Corrosion

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Also: Turn to RECORD and REPORT on Page 41 for Timely News on Corrosion Control

Complete Contents on Pages 4 and 5

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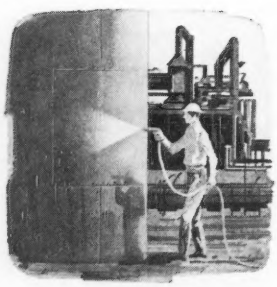

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S107		Oil			140° F.	
S108		Oil			280° F.	
330	Standard	Water or Brine		10° F.		
205	Standard		Fresh Water or Brine	—60° F.		Sweet and Sour Oil Corrosion
206	Standard	Fresh Water	Brine	5° F.		
207	Standard	Oil	Fresh Water	— 5° F.		
208	Standard	Oil		—15° F.		
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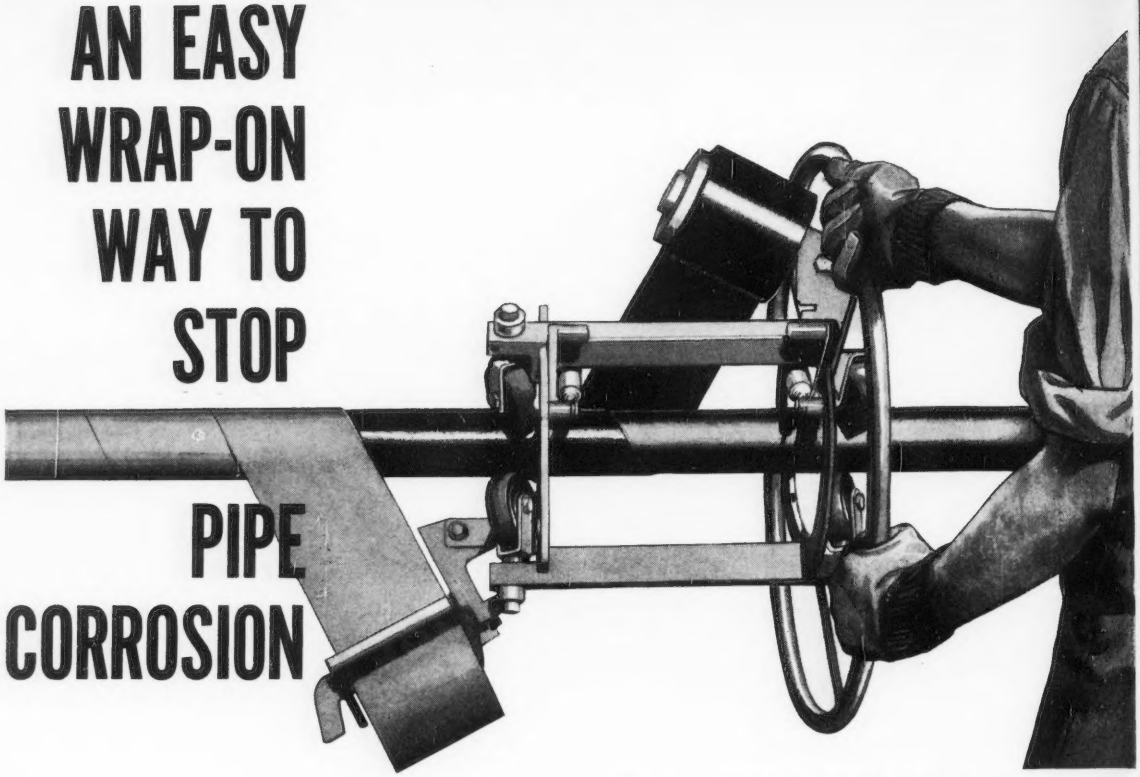

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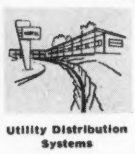

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This Month in Corrosion Control . . .

WHAT PLASTIC TRADE NAME goes with what generic term and who makes it? Answers on 44 plastic materials are given on Page 40.

HOW STEEL CORRODES IN BRINE at high oxygen pressures and at varying pH's is explored in an article beginning on Page 94.

PLANT TESTS of a recording electrical resistance corrosion meter are described and some of the precautions necessary for reliable results may be found in a fully illustrated article on Page 99.

HOW TO COPE WITH refinery corrosion when processing aggressive Canadian crudes is the subject of an article by a Canadian corrosion engineer. Turn to Page 109.

WHAT HAPPENS to zirconium and uranium exposed to organic coolants? Results of tests up to 400 C are given and an account of the mechanism offered in a two-part article beginning on Page 115.

WOOD STAVE PIPE carrying water to a hydroelectric generator station is expected to last 50 years. Photographs show this 10-foot diameter pipe on Page 41.

POLYESTER-GLASS was used to cover a corroded ventilating system of galvanized ducts as an alternative to replacement. Fragments of the corroding ductwork will be screened from the ventilating system. Turn to Page 43.

CONCRETE PIPE STRENGTHENED with pre-stressed steel reinforcements can be cathodically protected economically. A thorough discussion begins on Page 123.

A 16mm SOUND FILM in color has been produced for showings before groups interested in sandblasting. General topics covered by the film and its source are given on Page 44.

EXPERIMENTS TO OVERCOME columbium's poor oxidation resistance have been conducted by the U. S. Naval Research Laboratory. On Page 41 is described a coating developed by the Navy to meet requirements for a columbium coating. Columbium is important for its applications in nuclear reactors, jet engines and other high temperature uses.

FOCUS on COATINGS

A WEALTH OF INFORMATION on coatings systems used successfully in 17 Western states by the Bureau of Reclamation is given in an article beginning on Page 9. Results of laboratory and field tests of numerous systems suitable for fresh water exposures are given.

ADVANTAGES OF CHEMICAL CLEANING over mechanical cleaning of surfaces inside pipelines to be coated in-situ are described on Page 15. Techniques of using a newly designed flexible coating plug are described.

FOURTEEN POINTS defining a good maintenance coating are given on Page 22.

USES AND ATTRIBUTES of zinc-filled inorganic materials being used with increasing frequency in severe environments are covered in a timely article beginning on Page 24.

BETTER UNDERSTANDING of why paints behave like they do will come to those who read the article on molecular structure and pigments beginning on Page 32.

ORGANIZATION AND ADMINISTRATION of an industrial maintenance painting program is covered in an NACE report prepared by Task Group T-6D-3. Turn to Page 135.

CONTINUOUS FLUOROSCOPING of large diameter pipe welded seams has been developed, using a combination X-ray and television system for speedy checking of flaws in welded seams. A photograph of the X-ray head of the fluoroscoping unit is shown on Page 42.

OPERATION PIG SQUEAL, as explained on Page 42, is literally getting the last squeal from natural gas. Large dry adsorption units now recover several by-products which were avoided in the past for economic reasons.

CORROSION LITERATURE is growing rapidly. Eight reviews of some recent books on corrosion control and related topics are given on Page 44 in "Book News."

PLUMBING CODE AMENDMENTS to improve the corrosion resistance of utility lines into homes have been adopted in Fort Worth, Texas. The three main stipulations of the amendments are given on Page 46.

FIVE EUROPEAN MEETINGS dealing with corrosion control are listed on Page 43. These meetings are scheduled this year in Germany, France and Spain.

FIVE-WEEK REFRESHER COURSE held recently in India indicates the world-wide interest in corrosion control. See story on Page 46 for details.

NEW INFORMATION on the effect of and relationships among organisms found in secondary oil recovery systems will be found on Page 132.

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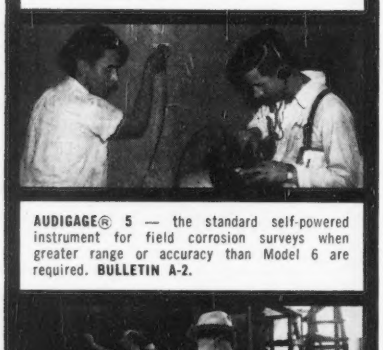

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AN EDITORIAL

Talk Still Key to Communications

NO MATTER HOW MUCH we struggle against admitting it, talk remains the leading method of communication among humans. There is some reason to believe that the lead is substantial. There is some hope that the lead is not increasing.

This stems from the unavoidable consequences of our learning to speak and hear language before we learn to read it. It also has a strong connection with the emotional and kinaesthetic factors involved in the spoken language with its associated inflections, tones, emphasis and volume. Some students of language believe gesture and facial expression help materially in conveying meaning, although the extent to which this is true may be challenged with respect to technical communications.

This may explain, in part at least, why meetings which bring technical men together for verbal exchange of information are so popular. It explains also why such meetings may be of growing significance, because of the uncomfortable realization that modern technology is fast outstripping our ability to keep up with it. It also may explain what many consider a regrettable waste—the custom many technicians have of ignoring printed information available and preferring a verbal opinion, no matter how general, to examination of the printed facts.

A committee of the National Academy of Sciences-National Research Council (does the hyphenation indicate over-organization?) calls for a better dissemination of research information as one means whereby pressing problems concerning materials may be solved. There is undoubtedly considerable room for improvement in the dissemination of research information. There is probably more room for improvement in the use of existing stores of information. Communication requires both a sender and a receiver.

From the viewpoint of an organization that has done considerable work over the past 15 years collecting, classifying and publishing information, there is a vast area of indifference to printed data. For every organization that customarily searches the literature for data, there are hundreds, maybe thousands, that do not. Some organizations fail to explore the literature because their resources do not permit it, or because they are not located near adequate sources. Others, with adequate resources, located near research facilities, fail to use them for reasons which are obscure.

It seems likely, therefore, that much of the progress being made in collecting and classifying information—plus electrical scanning and all the other time-saving methods being developed to improve access—may be wasted unless more interest is developed in using the services so created.

In the meantime some extension of the service offered medical practitioners might well be considered. This consists of magnetic tapes on which have been transcribed verbal digests of technical information. The service is divided into specialities, so the pediatrician doesn't have to listen to material useful only to the optician, etc. The doctor is supplied with a portable transcriber, which permits his listening to the tapescripts while driving his car, taking a bath or pursuing some other activity.

This type of service should please an engineer so anxious to learn what is happening that he is willing to devote his leisure time to this kind of activity, or who wants to give his overworked eyes a rest. In the meantime, for most people, the surest way to avoid wasteful duplication and costly mistakes is to use indexes and bibliographies.

Developed to its utmost extent, verbal communication will never equal the permanence or exactness, at least for technical communications, that the printed word gives. Improved graphical presentation, in the way of diagrams and illustrations, especially when the use of color is significant, will materially improve the printed version. Improvement should be the aim of all concerned.

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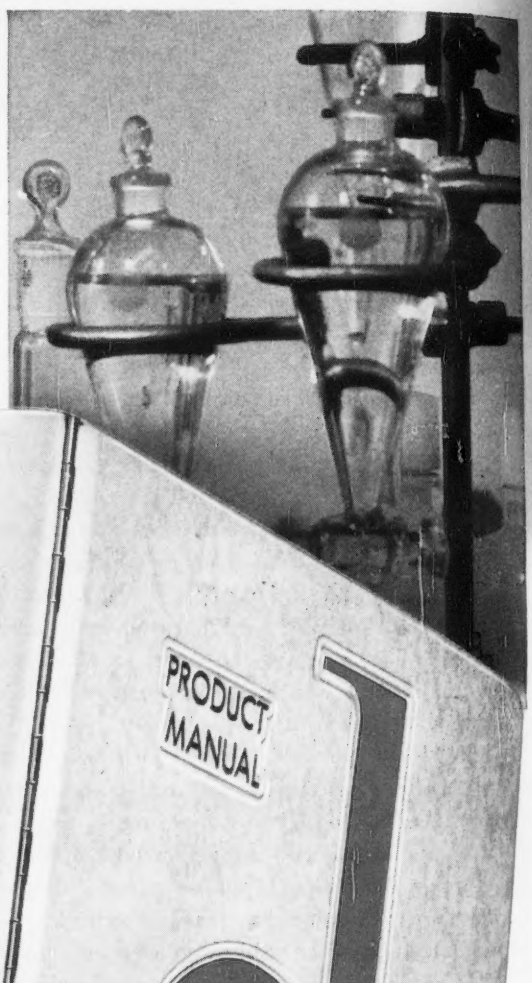

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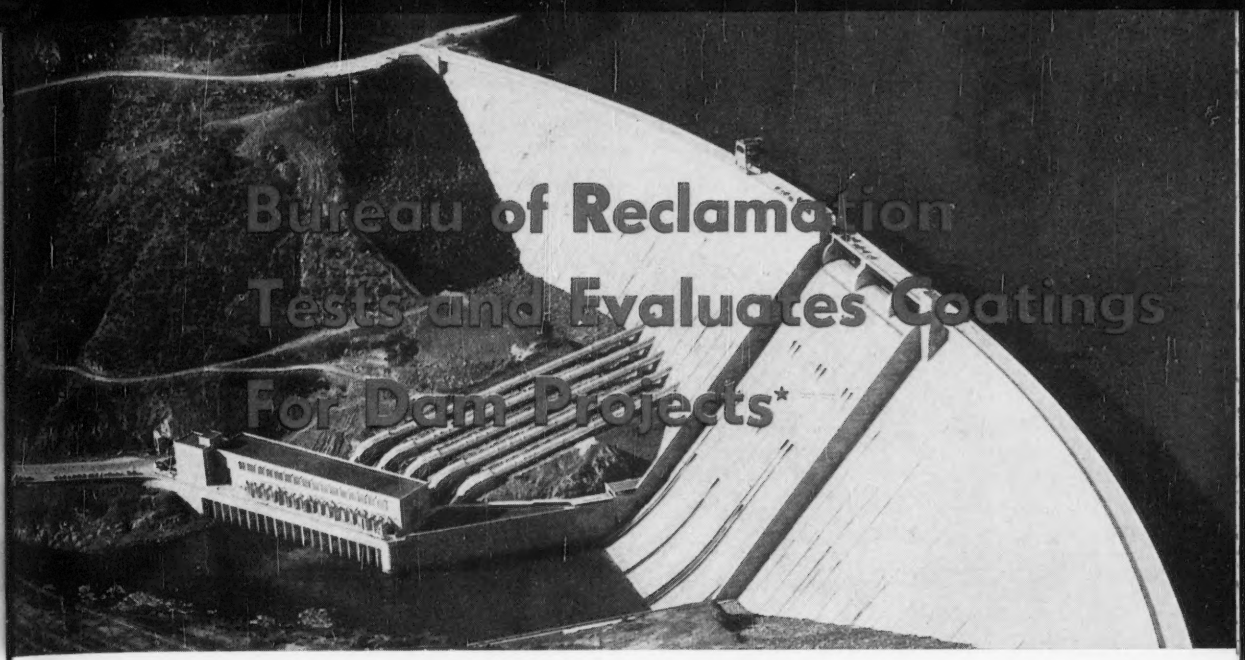

Bureau of Reclamation Tests and Evaluates Coatings For Dam Projects*

Abstract

Describes the Bureau of Reclamation's use of protective coatings to control corrosion on metalwork in variable fresh waters of the 17 western states. Standard specification materials are used successfully. Evaluation of new products and special tests are discussed to show the Bureau's use of tests for selections of new materials. Emphasizes importance of proper application of coatings under field conditions and of inspections at all stages of coating work. **5.4.10**

TECHNICAL TOPICS

TO CONTROL corrosion on vital metalwork in water conservation projects and structures in the 17 Western states, the Bureau of Reclamation relies primarily on protective coatings. This article discusses coating selections for the most important exposures and the inspection and quality control which are instrumental in achieving ultimate coating performance. A review is given of the Bureau's laboratory and field evaluation testing of new coatings.

Coatings Being Used

In major Bureau structures, several different fresh water corrosion environments will be found. Because penstock piping* usually is filled, coal tar enamel provides excellent protection. For buried piping and other water-bearing piping exposed aboveground and always in service and thus not subject to severe temperature fluctuations, coal tar enamel or cement mortar is used. However, for piping exposed aboveground that may be empty for extended periods, a three-coat vinyl resin paint[1] gives satisfactory protection. This coating has shorter durability and requires more maintenance than coal tar enamel.

Other metalwork associated with the penstocks such as butterfly valves and wicket gates through which water passes to the generators usually is coated with cold-applied coal-tar paint.[2] At the head of the penstock, trashrack metalwork, difficult to coat because of its shape, has been effectively protected by dipping in coal-tar pitch.[3]

Portions of radial gates used to control water flow are exposed to water and atmospheric exposures. A six-coat vinyl resin paint[4] provides excellent protection against corrosion and resistance to abrasion and sunlight on large gates.

Smaller gates on turnout structures usually are protected with phenolic red-lead primer[5] and phenolic aluminum topcoats; however galvanizing has been permitted as an alternate to painting.[6] On small turnout gates near Yuma, Arizona, a zinc coating applied by flame spray is proving effective in the corrosive waters of the Colorado.

The exterior of buried piping will be in an environment including most of the corrosive effects of fresh water immersion with the added potential damage to a coating from placement of backfill materials and from subsequent soil stresses when the pipe is in service. Extensive laboratory tests[7] were conducted by the Bureau to ascertain which pipe wrapping systems provide protection against damage to the coating from backfill and soil stress. These tests indicated that good protection against corrosion and damage to the coating can be provided by cement mortar or coal tar enamel. Integrity of the coal-tar enamel coating must be assured by also specifying one or more embedded or bonded wrapping materials. These include glass mat or fabric, coal tar saturated asbestos felt and Kraft paper outer wraps.

Protection of the Bureau's metalwork must be planned for 50 years and longer as opposed to the much shorter expected service periods in other corrosion atmospheres such as in an industrial plant where obsolescence is more of a governing factor. To accomplish this long-term protection, standard specification coatings mainly have been used with good results. Among these, coal tar enamel and cement mortar have given excellent service. Among the thin-film paints, vinyl resin-based paints have shown good protective qualities.

(Continued on Page 10)

★Revision of a paper titled "Reclamation's Use of Protective Coatings for Submerged and Buried Metal Work" by Paul W. Lewis and J. L. Kiewit, Bureau of Reclamation, Denver Federal Center, Denver, Colo., presented at the South Central Region Conference, National Association of Corrosion Engineers, October 12-15, 1959, Denver, Colo.

*A pipeline for delivering water from the intake in a dam or reservoir to the turbine.

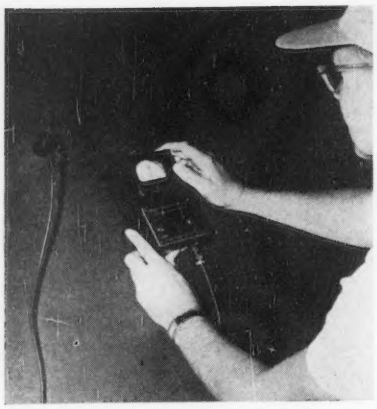

Figure 1—An inspector uses a surface temperature gage to determine if metal surface is above the minimum temperature for painting. This is one of several tests required during application to assure a sound coating.

Bureau Tests—

(Continued From Page 9)

Quality Control

Effective protection of metalwork involves not only correct selection of paint materials but also quality control testing if the best service from paints selected is to be realized. Particular batches of paint delivered to the job site are checked for conformance to standard specifications.

Job Site Application Inspection

Proper application of the protective coatings, considered to be at least as important to corrosion control as paint selection and quality control, often is more difficult to accomplish. Unlike other phases of construction, the quality of an applied coating may not be assessed readily by a final examinatin and knowledge of a few readily measured materials properties. That each step in applying paint has been done properly must be confirmed at the time of application. The Bureau insists on full specifications compliance at the time the job is accepted. Job site painting proceeds under such a wide variety of handicaps (weather, accessibility and shape of the metalwork) that it is sometimes remarkable that results are as good as they are. Field inspection is the tool which assures good results.

Quality of surface preparation is fundamental to the performance of coatings in fresh water immersion. Paints purporting to immobilize rust by one means or another have not been proven for immersion exposure to the Bureau's satisfaction. Removal of rust, dirt and mill scale by sandblasting remains the best field method of surface preparation. Sandblasting is considered essential preparation for any continuously submerged coating. Inspection of the cleaning by Bureau personnel at the site assures that the "sandblasting to base metal" requirement of Bureau specifications has been met, thus removing all contaminants and providing mechanical adhesion of the coatings.

Following surface preparation and during application of paint, the inspectors make a variety of simple but important tests, such as the bond and continuity testing of coal tar enamel and thickness and application temperature for all paints. Another test is checking of surface temperature as shown in Figure 1.

Laboratory Evaluation Testing

To save the cost of field failures, four laboratory tests are used by the Bureau to eliminate obviously unsuitable materials and to give a strong indication of fundamentally improved corrosion protection offered by new products. These tests include (1) fresh water immersion,[8] (2) salt spray fog box,[9] (3) outdoor weathering exposure[10] and (4) Weatherometer.[11]

In addition, special tests are devised to evaluate coatings for special needs. An example is the soil stress test of coatings for buried exposure still in progress. Another special test was begun when the question arose as to which coatings would best resist the effects of abrasion or erosion from sand- and silt-laden water in penstock or siphon piping. Eight-inch-diameter, eight-inch long pipe sections were lined with coatings the Bureau uses and with others being evaluated by the laboratory. Test sections were sealed to contain a sand or gravel slurry and then rotated for several hundred thousand revolutions. In a progress report,[12] cement mortar, neoprene, coal tar enamel, a catalyzed phenolic coating, pipeline asphalt enamel and a high penetration asphalt are indicated as having the best erosion resistance of about 15 linings tested to date. Selection of a particular lining for use in siphon or penstock piping where erosion is expected would, of course, depend upon a number of its characteristics. This test, however, has provided valuable data concerning erosion.

Field Evaluation Testing

Often, laboratory tests do not give complete performance data on a coating; much remains to be learned in the field. Accordingly, the Bureau further evaluates coatings showing promise in the laboratory by checking larger areas of these coatings in a field test. In the Shadow Mountain Reservoir test for coatings on exposed irrigation piping, which carries water in summer and is empty in winter, 30-inch diameter pipe sections were coated and lined, then trucked to Shadow Mountain Reservoir in the Colorado mountains for exposure. They were immersed during the summer months in the inlet canal and then stored on the shore for the winter. Considerable information was gained from this test during six years' exposure.[13] Briefly, some of the more important results are given below.

1. Coal tar enamel demonstrated excellent protective qualities but did not perform satisfactorily when extreme cold was involved. Hairline cracking was found even in 10-penetration enamel after several years, and the damage worsened progressively as the penetration decreased. Considerable portions of enamel, having penetration below 5, disbonded and spalled off during the first winter's exposure when a —41 F temperature was recorded. Rusting progressed very slowly and caused negligible damage to the metal at cracks in the enamel. Nonetheless, enamel is not considered a suitable coating for the aboveground cold weather exposures.

2. Cement mortar containing entrained air and applied one hour after mixing withstood the exposure, sustaining only a few hairline cracks which may have been caused by handling as well as by drying shrinkage and temperature changes. However, caution is indicated by the poor performance of another mortar lining tried in this test. This mix with no air entrainment exhibited excessive drying shrinkage and cracked and spalled severely, failing in less than two years.

3. Vinyl polysulfide and neoprene paints have done very well, as have Bureau of Reclamation specification paints, cold applied coal tar paint CA-50 and VR-6 vinyl resin paint.

Another major field test was begun at Shasta Dam 10 years ago. After 8 years' service, the phenolics and vinyls predominate among the undeteriorated linings. Coal tar enamel was unaffected by exposure in the penstock.[14]

(Continued on Page 12)

* A measure of plasticity as indicated by the depth to which a specified needled under specified load will penetrate the material. Units used are tenths of a millimeter. Test is performed according to ASTM Designation D5-52 at 77 F with 100 g bearing for 5 seconds, except that the Bureau of Reclamation requires that approximately 1/32 inch of the exposed surface be removed by cutting or scraping before testing.

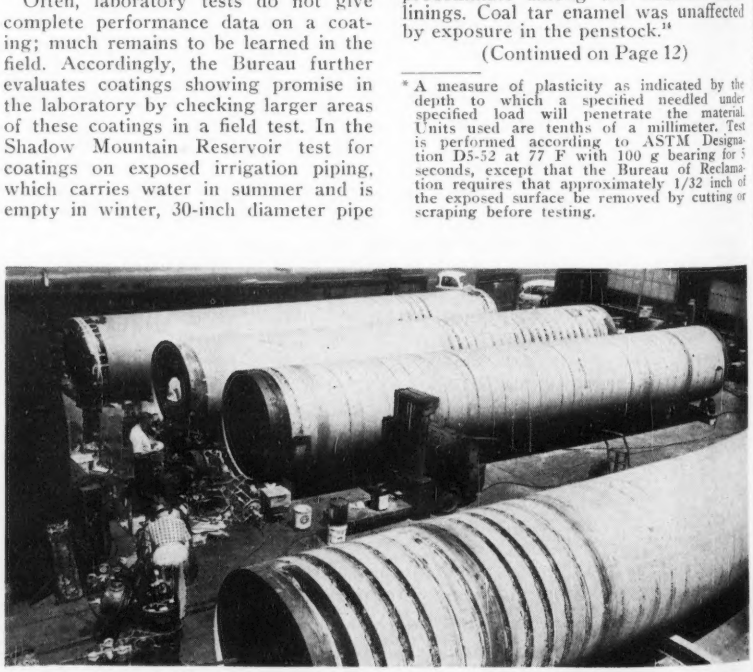

Figure 2—Forty-foot long, six-foot diameter pipe sections are shown in the pipe fabricator's yard where 36 coating systems were applied to the interior surfaces for an experimental protective coatings test. Pipes will be installed in a siphon on the Southside Canal, Collbran Project, near Grand Junction, Colorado.

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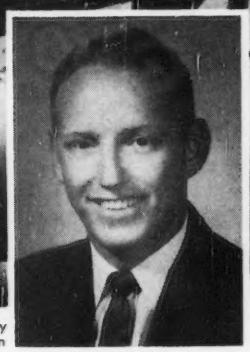

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Bureau Tests –

(Continued From Page 10)

New Linings Test

To check new lining materials developed, a large scale test for field exposure is being conducted at the Southside Canal, Collbran Project, near Grand Junction, Colorado. In August, 1959, 280 feet of six-foot diameter piping were lined with experimental materials at a pipe fabricator's plant in Denver (see Figures 2 and 3) and then transported to the project site. When installed as part of a buried siphon, the piping will be exposed to continuous fresh water immersion with water velocities to 8.8 feet per second during the operating season. During the winter months, this portion of the siphon piping usually will be empty. The linings will be inspected after the first, second and fourth years of service and thereafter as indicated by their condition.

The Southside Canal test includes 36 different coating systems using 42 materials. Each combination of materials applied has been considered a separate coating system; thus, adjacent coatings may differ only in that a metal conditioner or a special primer was used. Approximately 22 basic linings are represented in the 36 coating systems. Linings were applied as closely as possible in accordance with manufacturer's instructions and with his representative on hand to advise on procedures and techniques to obtain best results. Thickness and characteristics of each coat and the application conditions were recorded; appearance and continuity of the final lining also were noted.

There is a trend toward use of multicomponent systems in the coatings field. In the Shasta test conducted 10 years ago not one lining included a material of the multicomponent type, that is, one which requires mixing two or more components shortly prior to application, producing a material with a limited pot life. In the current Southside Canal test, 21 systems had one or more coats of a multicomponent paint. The Bureau considers that various new resins and modifications have performed well enough in laboratory screening tests or have achieved sufficient prominence in industry to justify inclusion in this field test.

Also represented in the test are neoprene and chlorinated rubber, aluminum and zinc as sprayed metals, zinc as the pigment in several paints, vinyl red-lead paint and asphalt enamel. To provide controls and a comparison of present Bureau coatings for this exposure with those which may someday replace them, Type IV red-lead and VR-3 vinyl resin paints also were applied, and coal-tar enamel protects the remainder of the siphon interior.

The linings in this test should provide some valuable and interesting comparisons of the new resins and zinc coatings.

Among the new resins, three samples are of the epoxy coal-tar combination type, which laboratory tests and limited service data indicate should show good performance might be expected. Straight urethane is represented in one lining, and urethane is combined with coal-tar in another. Two linings are of the modified phenolic and epoxy modified phenolic type. Straight vinyl and epoxy resins are included as components of mastic paints.

The protective possibilities of zinc coatings also are being checked in this test. Zinc is exposed as a flame-sprayed lining and as the essential pigment in both organic and inorganic vehicles. Zinc also was topcoated with vinyl or phenolic materials. Zinc alone protects steel by sacrificing galvanically at small exposed steel areas. Duration of such protection should be indicated by this test. In theory, organic topcoats should offer additional protection; however, their combination with zinc should lengthen their period of effectiveness.

Figure 3—A lining material is being applied by conventional air spraying as part of the Southside Canal coatings test. Other materials were applied by brushing, rolling and hand daubing.

Another advantage may exist when deterioration of the topcoats occurs. Maintenance in the form of touchup painting or a complete single topcoat may almost restore the system as a whole to its original condition before the ferrous-base metal has been attacked. In maintenance, sandblast surface preparation may be replaced with cheaper and more expedient wire brushing. Continued maintenance in this manner may offer the possibility for long-term protection of the base metal.

What the Bureau expects to learn from the Southside Canal field test is noteworthy. Durability is a primary consideration. A rugged material having a potential 20-year service life with a minimum of maintenance is sought in this test. The desired lining should be suitable for exposure in empty steel piping aboveground and must resist wetting and drying, freezing and thawing and extremes of temperature.

Also of interest are the manner and ease of lining application in the field where conditions often are less than ideal. Heat and cold, high humidity, difficult shapes to coat and limited access generally complicate the coating application job. Requirements for highly skilled applicators or specialized and unusual equipment add to the cost and may make the best quality of work difficult to obtain in some cases. For these reasons, particular note was taken during application of the Southside Canal test lining materials of the complexity of the operation. A record was made, for instance, where extraordinarily high quality surface preparation was required, where nature of material raised obstacles and where spray techniques were likely

(Continued on Page 14)

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Bureau Tests –

(Continued From Page 12)

to baffle the ordinary painter. Fortunately, few serious problems arose; most of the linings appear well adapted for Bureau field application.

Cost will strongly affect eventual selections from among the better performing lining materials. Initial cost of a coating is considered to include material costs and the applicator's expenses in coping with field conditions while applying the required number of coats. If these costs are reasonable and the expected long service with minimum maintenance is realized through the use of superior coating materials, the ultimate objective of protective coatings investigations will be achieved in lower annual cost per square foot for corrosion control.

Summary

The Bureau's more commonly used coatings have been given for the principal corrosive fresh water and buried exposures associated with large and small reclamation projects. The desired end product is a durable, economical coating which will protect metalwork with dependability and a minimum of maintenance. Such a coating will result not only from correct selection, but from careful attention to proper application to a well prepared surface. Diligent inspection insures success of the application. Also, control testing of coating materials is essential to maintain quality standards. These are the steps necessary to assure a successful coating for the protection of Bureau metalwork against corrosion.

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13. Bureau of Reclamation Protective Coatings Laboratory Report No. P-58, Experimental Coatings on 30-inch-diameter Pipe Sections Exposed at Shadow Mountain Reservoir—Second Interim Report.
14. Bureau of Reclamation Paint Laboratory Report No. P-72, Eighth-year Evaluation of Experimental Test Linings in Shasta Dam Penstock.

Slide-Talk Available On Surface Preparation

A color slide presentation on metal surface preparation by sandblasting is available on loan from NACE Central Office. The talk is based on a paper by E. W. Oakes, Clementina, Ltd., Houston, presented at the NACE Annual Conference in Chicago, 1959. The illustrations used are 35mm color slides.

Requests should be sent to Gilbert Rolak, 1061 M & M Bldg., Houston 2, Texas.

Procedures and Techniques for

Internal Cleaning and Coating of Plant Piping In-Place*

Abstract

Outlines development of in-place method of cleaning and coating of pipelines during 1947-48. Discusses cleaning and coating methods and explains suitable procedure for selection of suitable coating. Gives five case histories of in-place coatings used to reduce internal corrosion.

5.9.1

Introduction

IN-PLACE CLEANING (in-situ) and coating of sour crude oil and sour natural gas pipelines was undertaken during the winter of 1947-48 in West Texas to protect the interior surfaces of pipelines from the corrosive attack of salt water, H_2S and CO_2 gases entrained in the oil and gas stream. Cleaning methods used were largely mechanical, aided by the more highly volatile petroleum solvents. The coating materials were formulated of polyvinyl chlorides made for routine spray application, applied in place by pipeline pigs which squeezed or rolled the coating onto the pipe's interior surfaces.

After this initial in-place cleaning and coating in 1947-48, extensive field testing of this method was conducted to determine its performance under field conditions. Neither the cleaning procedures nor the coating method were adapted to the twisted piping systems of chemical plants or to the critical service conditions of process lines.

The mechanical cleaning method did not prepare the pipe surface to the satisfaction of plant engineering and maintenance personnel who must consider possibly disastrous effects of premature coating failure. Design of the coating plugs prevented application of a concentric coating on fabricated bends and swings. This problem was solved by short coating runs between bends which increased down time and the pay out time of the job.

Development of chemical cleaning and a more flexible coating plug made in-place protection of plant lines a reality.

Chemical Cleaning Process

In-place chemical cleaning of pipe must overcome two inherent disadvantages: (1) identification of the internal contaminants can be made only on a qualitative basis and (2) bulk and weight of contaminants can be removed from the pipe only at the open ends.

These two disadvantages are opposed by the one great advantage of in-place cleaning—that within the confines of the pipe, all contaminants can be exposed to chemicals and solvents whose minimum potency and contact time can be carefully regulated. As an example: cleaning of new steel pipe contaminated with mill lacquers and oils, mill scale and atmospheric corrosion products is accomplished in the following five steps:

1. Mill lacquers are removed by high order petroleum solvents usually selected after tests on pipe samples. These solvents, partially effective in removing oily residues, leave an oil film.
2. Degreasing is accomplished with water solutions containing detergents embodying emulsifying and wetting agents. These solutions followed by heavy water flushes leave the line free of grease and in a water-wet condition.
3. Mill scale and the bulk of atmospheric corrosion products are removed by flushes of hydrochloric acid, also embodying wetting agents. Strength, volume and contact time of these solutions are based on experience with previous lines, modified by the success of the first few acid washings on the specific line being cleaned.
4. After neutralization, drying and some mechanical scrubbing, the line is clean but lacks tooth—an anchor pattern which will assure optimum coating bond. This tooth is obtained by washing the pipe with unheated solutions composed primarily of phosphoric acid.
5. The line is again dried, excess phosphates removed, flushed with solvents compatible with the coating.

Cleaning of an old line follows the five steps above modified by displacing the line and by removal of any chemical residues remaining. This removal might require other reagents than those listed, but such reagents or solutions can be chosen only after inspection and laboratory experimentation.

Coatings Selection and Testing

Selection of suitable coatings for chemical plant exposures is a simple matter if satisfactory records are available of in-place coatings in similar service. Some experience on this matter is given in Table 1.

If such records do not exist, a testing procedure is required. One method of selecting a suitable coating for a new exposure is to check the technical literature on resistance of basic resins and coating formulations for a lead to a possibly successful coating. If such a resin or formulation is found, various samples are placed under accelerated laboratory tests. From these samples, the most promising, if any, is selected for field evaluation.

For field evaluation, this coating is formulated to obtain mechanical properties necessary for successful in-place application. Some of these properties are high solids concentration, high percentage of resin, high viscosity, flat temperature vs. viscosity curve and specific solvent balance.

This coating should be applied by field in-place methods to pipe samples removed from the proposed service and then tested under operating conditions for three to six months. This rigorous test should show conclusively whether or not the coating will give satisfactory service. Test procedure should be short cut or modified.

Application of Coatings

Application of most resins is similar and accomplished as follows:

Specially designed rubber plugs are placed in the loading joint at the upstream end of the line. The desired amount of coating material is then pumped between two plugs, forcing the lead plug down the line. After all the coating is in the line, air pressure is applied to the line and a calculated back pressure is maintained. Plug construction makes it possible to hold the coating material under compression, forcing it into any crevices or imperfections of the pipe wall.

When the coating train reaches the downstream end, the excess coating is removed from the line. This excess is measured and, if the proper amount has been left in the line, the deposited film is ready to be dried.

The plug method of application adapts the basic advantages of the dip or roller system of coating application. Necessity for good wetting and flowing properties of the coating is reduced since the coating is forced into intimate contact with the metal surface. Since the plugs are propelled down the line by differential positive pressures, the column of liquid coating material between the coating plugs is under a positive pressure. This pressure forces the coating into the most minute crevices and pits in the pipe wall and will displace any contaminants which would have been trapped under the film, if the coating had been applied by a spray gun.

In the pressure controlled application, the coating is applied in a continuous film without inferior coverage of joints. Required thickness can be achieved in one coat and still obtain a continuous film.

One of the major problems encountered in in-place application has turned out to be a major advantage. This is the drying of the wet coating in confined atmosphere, making close control possible of the drying rate, thus keeping the

(Continued on Page 16)

TABLE 1—Satisfactory Service of Coatings in Various Exposure

Coating	Salt Water	Potable Water	Propane Butane	AvGas Jet Fuel	Stearic Acid	50% NaOH
Polyvinyl Chloride	X	X				
Amine Cured Epoxy	X	X	X	X		X
Polyamid Epoxy	X	X				
Chlorinated Rubber	X					
Coal Tar Epoxy	X					

*Revision of a paper titled "In-Place Cleaning and Coating of Chemical Plant Piping" by W. T. Theis of Internal Pipeline Maintenance Co., Odessa, Texas, presented at a symposium sponsored by NACE Technical Unit Committee T-5A on Corrosion in Chemical Processes, L. W. Gleekman, chairman, at the 16th Annual Conference, National Association of Corrosion Engineers, March 14-18, 1960, Dallas, Texas.

Internal Cleaning—

(Continued From Page 15)

coating surface wet and letting the drying proceed from the inside out. Because solvent bubbles are not trapped by the surface filming over, a pinhole free coating is more easily assured.

Coating Case Histories

Typical case histories indicating some of the value of in-place applied linings are given below.

Brine Water Exposure

The owner company of a West Texas plant handling a large volume of saturated brine did not consider a closed system to be feasible. Economy necessitated the use of standard welded line pipe if the pipe could be protected from corrosive attack.

These brine lines, consisting primarily of 8-inch and 10-inch pipe, were coated internally in-place with an amine cured epoxy system which had proved satisfactory over many years' use in oil field salt water disposal systems.

The work was completed in December, 1957. At the last inspection in May, 1959, after two years' service, coatings were well bonded and showed no sign of deterioration. The pipe itself was completely protected.

50 Percent NaOH Exposure

A chemical manufacturing plant in California was using standard 4-inch welded pipe in a 50 percent NaOH, 140 F, delivery system. The plant could not deliver an iron-free product through this line; in-place coating was attempted as a possible solution.

The line was coated during March, 1957, with an amine cured epoxy coating selected after extensive testing. From the last report available in May, 1959, the pipe was still delivering iron-free NaOH.

Stearic Acid Exposure

In-place coating of standard iron pipe solved a scheduling problem at a West Texas plant under construction in 1957. When stainless steel pipe became unavailable for stearic acid service, standard 4-inch and 8-inch iron pipe was substituted with an amine cured epoxy system applied by the in-place method. Only the technical literature was consulted in selecting a coating because the construction schedule precluded any test procedures.

After being in service for over a year, the in-place coated lines were transporting stearic acid without contamination. During the second year's operation, however, small chips of coating were observed in the acid stream.

Aviation Gas and Jet Fuel Exposure

Government agencies and commercial aviation companies have strict specifications on the amount of micron size rust particles in acceptable aviation gas and jet fuel.

In selecting the best internal coating for a proposed aircraft fuel handling system, pipe coupons were in-place coated and tested for 12 months under conditions simulating the fuel system exposure. The coating tested, an amine cured epoxy, proved very satisfactory and was used on the new pipe system.

Potable Water Contamination

Potable water supplied to a gasoline plant through 19,500 feet of 4-inch standard pipe was contaminated seriously by rust particles of soluble and insoluble iron oxides which were products of internal pipe corrosion. From the line, the water was discharged into a supply tank and from there through a water softener into the plant cooling system. Rust particles deposited in ziolite beds destroyed the water softener's effectiveness, allowing hard water to be circuated through the plant. Iron particles also affected the water's potability.

This water line was internally coated with an amine cured epoxy system. During a 30-month service period, visual inspections made at various coupons and laterals showed the coating to be in excellent condition. No measurable difference in water contaminant concentration was found when chemical analyses at the well and at several points along the line were compared. Inspected after four years' service, the coating was still well bonded to the pipe at all inspection locations.

An interesting corollary to this coating application is that the C factor of the Hazen-Williams formula for this line has remained above 140.

DISCUSSIONS

Questions by Peter A. Kahn, Metcalf & Eddy, Boston, Massachusetts:

Has federal government authorization been received for use of toxic amine cured epoxies on domestic potable water pipelines? What methods are used to remove tastes and odors from pipeline after the amine-MEK material has been applied and before pipeline is placed in operation?

(Continued on Page 18)

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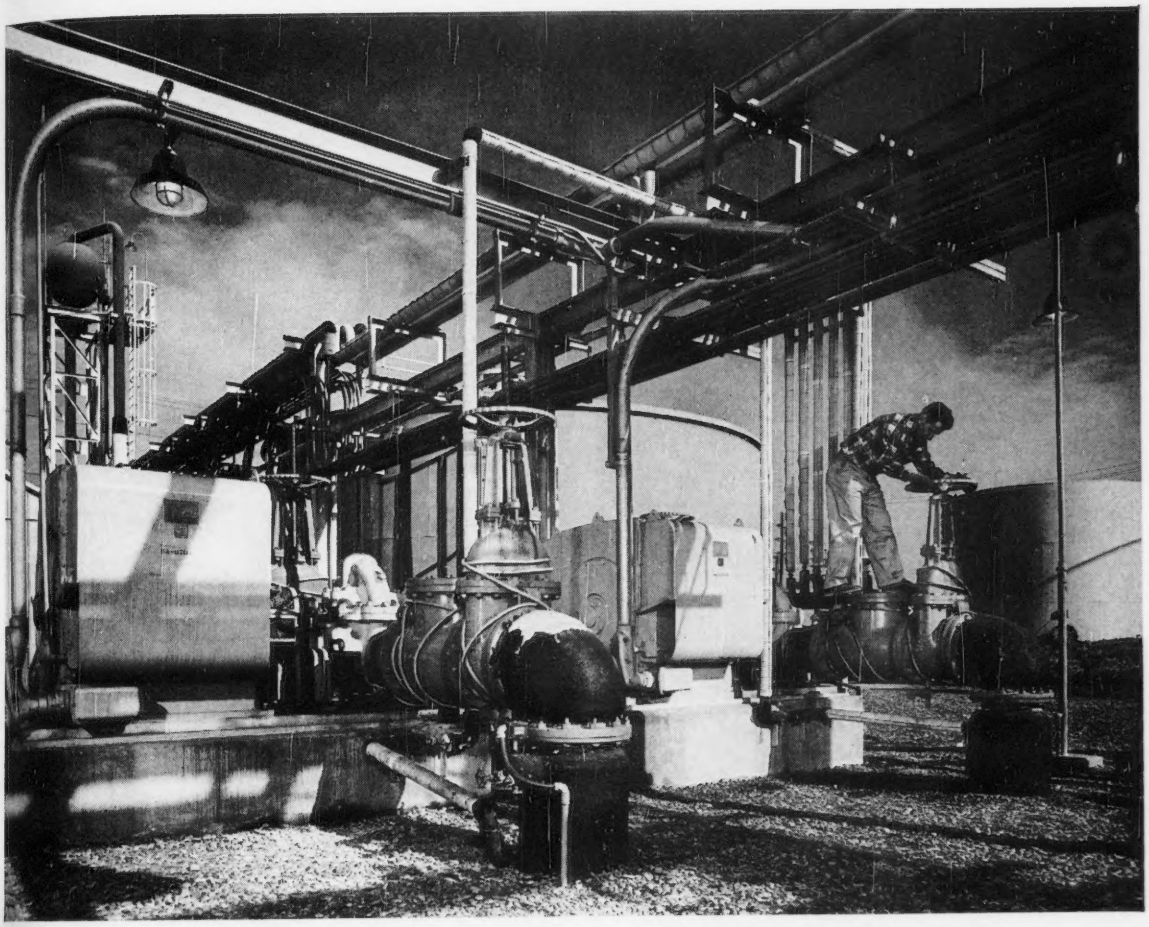

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Internal Cleaning—

(Continued From Page 16)

Reply by William T. Theis:

There is no direct means by which the government can approve or disapprove use of epoxy resin base coating materials on interior of potable water lines. In public domestic water systems, the state departments of health would be considered normally to have such control, and certainly the various committees of the American Water Association would be consulted. Two specific instances of approval can be cited:

1. The U. S. Food and Drug Administration, working with the Shell Chemical Corporation, gave its approval to use these materials in a large potable water line in another country in which the author's company was consulted.

2. The Texas State Department of Health grants approval, upon the application for specific permission, to coat water lines in Texas domestic public systems. The author's company has readily obtained this approval on a project-by-project basis.

In regard to the second question, the line after coating is thoroughly dried by pumping a large quantity of fresh air through the pipe to remove the volatile solvents and to afford time for coating to mechanically dry. After the line is connected to the water supply, the pipe is thoroughly flushed through its lower end to remove the remaining MEK odor traces. This, in our opinion, is 99 percent effective. The water after flushing may present a slight odor/taste for two or three days, generally to those who are acquainted with the fact that the line has been coated.

Comments by Joseph H. Walter, Procter & Gamble Co., Cincinnati, Ohio:

Although this has been entirely a technical presentation, I cannot divorce economics from an evaluation. Please comment in general on the economics of in-place cleaning and coating of pipelines and specifically on cleaning and coating of process piping in chemical plants.

Reply by William T. Theis:

The author, working for an engineering and contracting organization, appreciates the opportunity of discussing this service from an economic standpoint which, after all technical requirements are met, finally determines whether the service will be employed.

On field type or long continuous straight runs of one size of line, experience has shown in hundreds of lines coated that a great deal of pipes seemingly in bad condition because of internal corrosion, can be successfully repaired by cleaning, patching, and pressure testing and then coating for 20 to 25 percent of the pipe replacement and salvage net cost. Many lines planned to be abandoned were so reconditioned between 1948 and 1950 and today, ten years later, continue to have leak free records. New bare pipe installed in the same areas has been known to fail from the severe corrosion and intolerable leakage rates in 12 to 18 months.

The specific economic justification for internally, in place, cleaning and coating of plant process piping presents a similar type of problem. Given the cost of installation and some data on the number and cost of repairing subsequent system leaks, until replacement is required, chemical plant management can obtain comparative cost and payout time for use of this service.

Each installation has its own economic specifications, but the use of this lining service to replace stainless steel, aluminum or ceramic type linings installed in short mechanically connected joints presents some dramatic savings and a quick payout on original installations.

A final factor to be weighed is that in some special services, the best coatings offered might show a conservative life history of four to five years. In many installations, the substitute for coating might be so costly that a planned recoating every three years would be a simple matter to accomplish on a plant turn-around program and would still present the best payout.

Questions by L. W. Gleekman, Wyandotte Chemical Corp., Wyandotte, Michigan:

1. What is done about inspection of the coating in terms of thickness, freedom from excessive porosity and degree of cure in view of its general inaccessibility?

2. In view of the difficulty of inspecting the interior of a pipe line compared to a tank or tank car interior, what is the liability of the coating manufacturer and the lining applicator if a failure of the coating occurs succinctly in service?

Reply by William T. Theis:

1. This question succinctly outlines the basic problems that were encountered in the early internal, in place applications of pipeline coatings. Our experience has shown over many hundreds of field installations that the dry

(Continued on Page 20)

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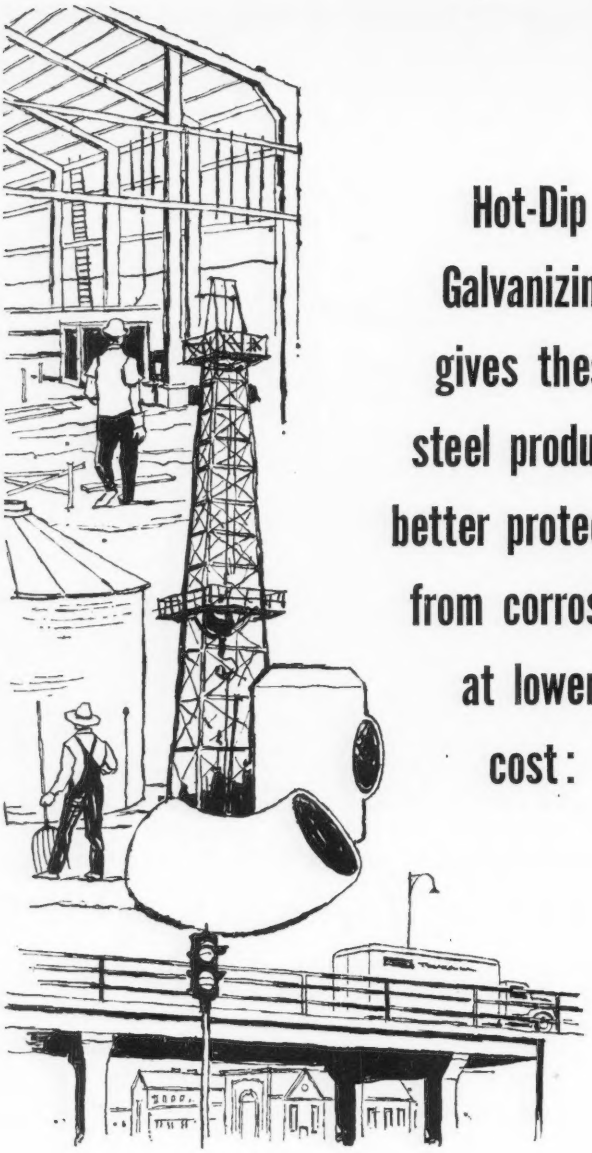

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Internal Cleaning –

(Continued From Page 18)

film thickness will be uniform and of a closely predictable thickness. This is accomplished by putting the correct amount of material in the line at the start and performing whatever operations are dictated by turns and convolutions of the pipe with the proper tools to get this material evenly on the pipe walls. If the net amount of material in the line is known, the average thickness can be calculated within plus or minus about one mil, including any variation that might be encountered between the top and bottom of the pipe. We believe the degree of porosity to be very low, closely approximating the best laboratory tests of the resin basic type. This is because, as outlined in the discussions,

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The curing of the applied film can be carefully regulated to keep the surface of the film solvent wet well through the chemical set time so that the small percentage of solvents in the liquid material can usually make their way through the film and escape into the atmosphere of the pipe for removal during the final stages of drying.

The contractor's company, of course, heartily endorses any program for the installation of temporary or test spools in the lines to be treated so that the owner company's engineering and inspection personnel may inspect representative points in the pipe during any stage of the operations.

2. This company cannot vouch for the practices of other applicators or for the companies which may formulate coatings purportedly for internal, in place application. Using any of the special coatings which we successfully employ from a limited group of suppliers, we stand ready within a reasonable period after installation and initial service to correct problems that occur which are chargeable to faulty workmanship. Our material suppliers, having approved the service in which their coatings is to be installed, guarantee to replace coating materials found defective or which fail to give protection in this service.

Question by D. B. Orr, 18 London St, London, England:

Will pipe coating cure and release all solvent? When film is in excess of 10 mils? Ten to 15 mils have been mentioned.

Reply by William T. Theis:

As brought out by photomacrographs

(Continued on Page 26)

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A Definition

What Is A Good Maintenance Coating?*

MAINTENANCE COATINGS are coatings which go beyond ordinary paint in adhesion, toughness, chemical resistance, and resistance to weather, humidity and water. They are designed for tough exposures and will prevent serious breakdown of the basic structure even though they suffer abrasions, holidays or imperfections. Also, maintenance coatings must retain good appearance even though subject to extreme weather conditions. They must resist the transfer of ions and be able to expand and contract with the surface over which they are applied. They must have these characteristics and perform these functions long enough to economically justify their price and application costs.

This definition applies some rather stringent requirements on a maintenance coating. Listed below are 14 properties which the ideal coating should have.

1. Excellent water resistance. The coating must withstand almost continuous immersion in water. It must withstand continuous wetting and drying and have a very low water absorption and moisture vapor transfer rate.

The moisture vapor transfer rate is the more important phenomenon. This is the action of water vapor in molecular form passing through an organic substance. Each coating material will have its characteristic rate, and generally it can be said that the lower the moisture vapor transfer rate, the better protection will be provided by an organic coating.

2. Resistance to ionic passage. The coating must resist passage of ions and act as a barrier to penetration of chloride, sulfate, carbonate or similar ions which on penetration of the film would start under-film corrosion.

3. Resistance to osmosis. This phenomenon has a great deal to do with coating life. It can be defined as the passage of water through a semi-permeable membrane from a solution of less concentration to one of a greater concentration. Because all organic coatings transmit moisture vapor, they are semi-permeable membranes, and as such this principle of osmosis definitely applies. From a practical standpoint, this principle applies to coatings exposed to water; if a coating is applied over an unclean steel surface, a surface containing chlorides, sulfates or other ions, the water vapor—as soon as it penetrates the coating—forms a concentrated solution at the coating-steel interface and water is drawn through the coating with resulting blistering and coating failure.

4. Resistance to electroendosmosis. Another reaction which causes coating failure, this phenomenon can be defined as the forcing of water through a membrane by an electrical potential in the direction of the pole with the same charge as the membrane. Most coatings are negatively charged and metal areas around even a small break in a coating are cathodic or contain an excess of negative electrons. Thus, where a break occurs, moisture tends to be forced through the coating around the break.

5. Dielectric strength. The coating must be highly dielectric to resist passage of any electrons which might exist from anodes set up in coating breaks.

6. Weather resistance. Excellent weather resistance is important because most industrial structures are subject to continuous weather exposure.

7. Chemical resistance. In addition to being resistant to ionic penetration, coatings must be generally chemically resistant because of continuous exposure to salts, acids and alkalies with a wide range of pH and to organic materials such as diesel oil, gasoline and lube oil. All these materials may be in continuous contact with the coating.

8. Adherence. The coating must be highly adherent. This is an extremely important property; strong adherence is required to overcome the physical action of osmosis, electroendosmosis and abuse from installation, repair, physical damage, etc.

9. Abrasion resistance. The coating must also be highly abrasion resistant. Any material which is not very tough, hard and resistant to shock would soon erode away from any area where abrasion is a factor.

10. Resistance to undercutting. The coating should not be susceptible to undercutting in areas which are damaged. Adhesion must be high and must be maintained even at a raw edge between the coating and the steel. Here a proper primer is usually essential—strong adhesion combined with general resistance indicates the use of a coating system with the primer for adhesion and one or more top coats for maximum resistance.

11. Inhibition. The coating should be inhibitive; should damage occur, the material of the coating will tend to minimize the break and tend to restrict corrosion even though bare metal is exposed.

12. Easy Application. The coating should be easily applied, an obviously important property in coatings for critical exposures. The size and design of most structures make application difficult. Even under best conditions there are many welds, corners and edges which are focal points for corrosion.

13. Easy touch-up and repair. In addition to easy application, the coating must provide easy touch-up and repair. The repair must be equally as effective as the original coating.

14. Age resistance. The coating should have a long life and the ability to maintain its protection effectively over a period of many years, even under widely different corrosion conditions.

When these requirements are considered, it is apparent that only a few basic materials really qualify as maintenance coatings. Of the organic materials, the vinyls and epoxies are the best examples. Chlorinated rubber base coatings may be included as may other new coating materials—chlorosulfonated polyethylene and the polyurethanes for examples. So far there is too little experience and too little knowledge of the proper formulation of the newer coating materials to qualify them definitely as adequate for general maintenance.

Of other newer materials that do qualify, inorganic zinc silicate coatings should be included. These have proved by several years' service over millions of square feet that they can perform in certain areas better than any other maintenance material.

★ Extracted from a paper titled "A Comparison of Synthetic Resin Coating Materials" by C. G. Munger, Amercoat Corporation, South Gate, Cal., presented at the North Central Region Conference, National Association of Corrosion Engineers, Cleveland, Ohio, October 20-22, 1959.

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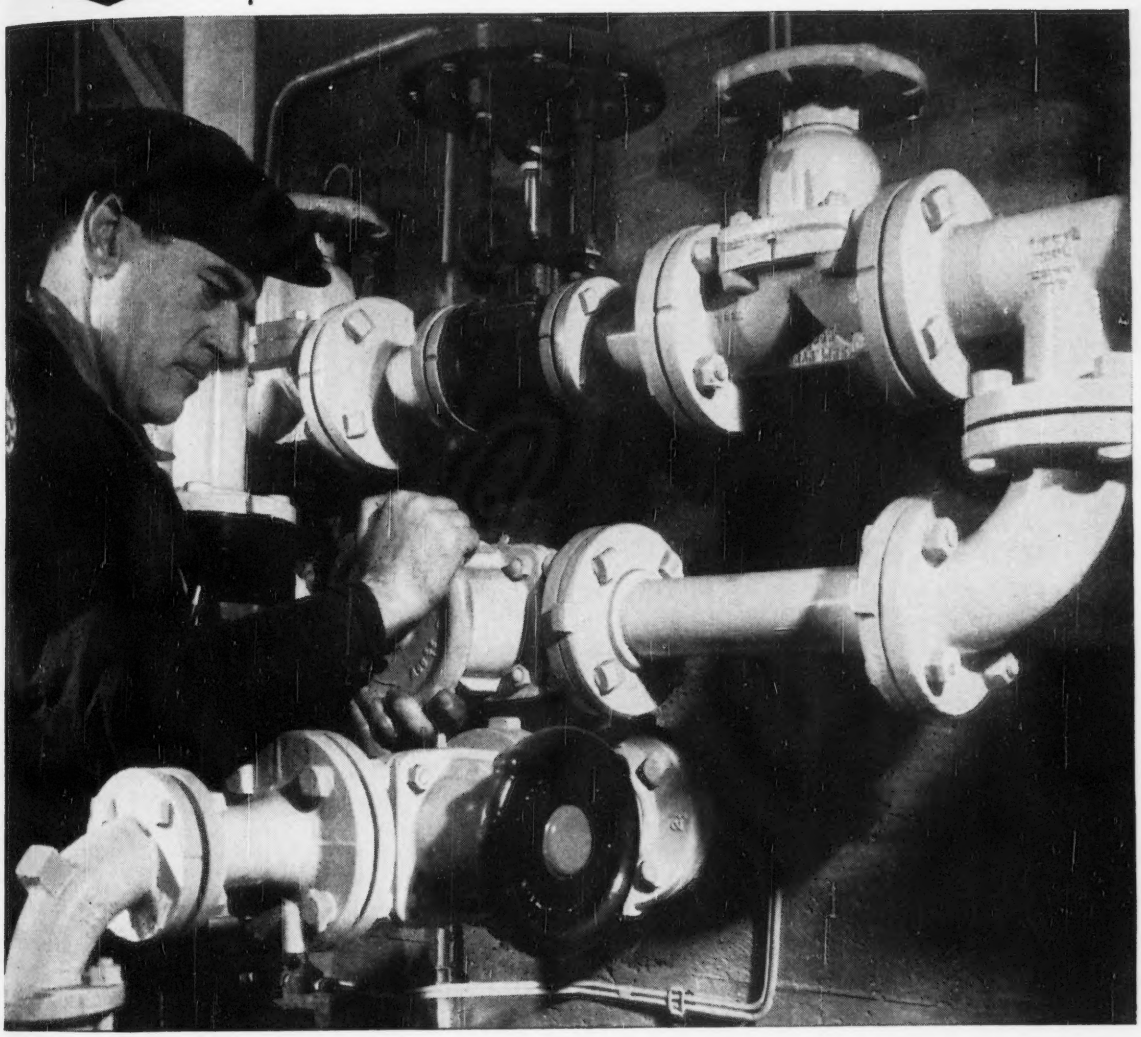

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Industrial Application of Zinc-Filled Inorganic Coatings*

- Application Requirements
- Service Characteristics
- Maintenance Routine

Introduction

RENEWED INTEREST in zinc-filled coatings has been shown in the last decade. Until recently, when protective coatings were thought of for use in severe chemical exposures or severe weathering conditions, first consideration was given to organic materials pigmented with stable, chemically-resistant pigments such as titanium dioxide, mica, aluminum silicate, etc., were considered. Pure metals, such as zinc dust, seldom were given serious consideration for use in coatings for such services.

Attempts were made to find coatings possessing very low moisture vapor transmission rates which could be applied pinhole-free. In comparing materials of like thickness, the one possessing the lower moisture vapor transmission rate would be considered the most serviceable. Further, with materials of like chemical resistance, the material with the greatest thickness was selected. The basic philosophy was to shield the material of construction from the environment.

Use of zinc as a pigment in appropriate vehicles allows the problem to be approached from another direction. When zinc-filled coatings are applied in one coat to a film thickness of 2 to 4 mils, they take advantage of the sacrificial metals in the conductive cured film to cathodically protect imperfections which will exist in any one-coat system.

Development of zinc-filled silicates have been developing at about the same rate as zinc-filled coatings with organic binders, such as epoxies and butyrals. While both types of coatings have their good points, it is the purpose of this article to consider the uses and attributes of the truly inorganic zinc-filled materials.

★ A paper presented under the title "Inorganic Zinc Coatings," by F. Parker Helms, Union Carbide Chemicals Co., Texas City, Texas, at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

Figure 1—Interior wall of floating roof tank protected by an abrasion resistant zinc coating. Deck and exterior are coated with zinc and vinyl system.

Abstract

Principal characteristics of zinc-filled and modern organic coatings are compared briefly. Self-curing types recently introduced have numerous good points and some deficiencies. Zinc-filled inorganics are compared to organics in resistance to corrosives, surface preparation, undersurface corrosion. Various uses for zinc-silicates are reviewed with comments on service experience. Problem involving overcoating is considered and some means of solving it presented. Materials are considered especially suitable for environments in southern areas near salt water.

5.4.2

Zinc-Silicate Coatings History

While the first inorganic zinc-silicate coatings were developed abroad more than 20 years ago, they made their appearance in the United States about 10 years later. New self-curing types of coatings now being introduced achieve a dried film without the addition of a chemical curing agent or the use of heat. Obviously these rely on a chemical action different from that of the zinc-silicates. While little is known of these reactions, they are based on zinc powder and a cementing agent.

One of these self-curing types has been tested on tank exteriors, tops and in solvent service, where it is giving excellent service. As a general anti-corrosive coating it has the advantage over some others of low cost, ease of application, fast cure, early moisture tolerance and rapid overcoating. More time will be required, however, to determine the comparative effectiveness of the material. Preliminary observations show it lacks abrasion resistance, has overcoating difficulties and a short life expectancy unless protected with an organic topcoat.

Long Experience Is Limited

Inorganic coatings with which there has been extensive experience over a period of years are limited in number. The inorganic zinc-lead-silicate coatings are the best known of this group. They are fully inorganic and are formed by a chemical reaction in place after being applied to the steel surface. Their outstanding properties, which are quite different from those of the organic coatings, are:

a. Unexcelled weather resistance either in humid tropics or drier cold areas.

(Continued on Page 26)

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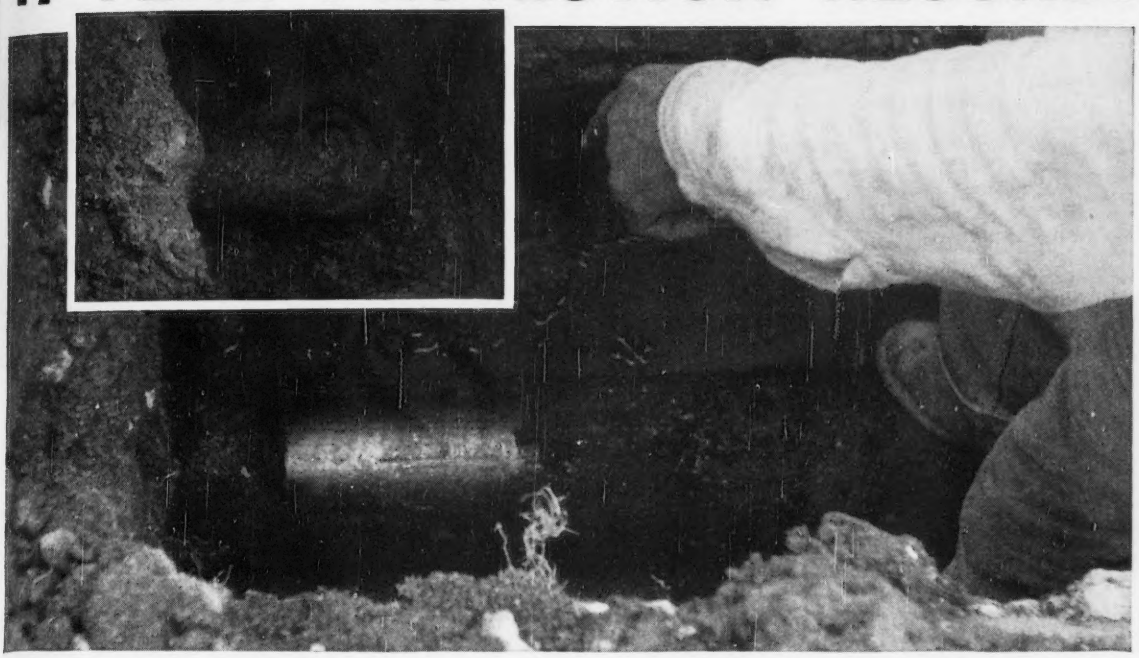

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Zinc-Filled Coatings –

(Continued From Page 24)

b. Increasing hardness, toughness, and adhesion upon weather exposure and aging.

c. Excellent resistance to alternate wetting and drying conditions.

d. Very tough and abrasion resistant within hours after application. Quick use and handling do not present a problem.

e. Outstanding resistance to most solvents, including esters, ketones, alcohols, aliphatic and aromatic hydrocarbons, Diesel oil, aviation gas, jet fuel, crude oil, etc.

f. Because of high zinc content, provide a definite measure of cathodic protection to areas exposed by scratches and abraded areas in atmospheric environments.

g. Excellent adhesion.

h. May be applied with conventional paint spray equipment or brush.

Like all others, it has some less desirable features:

a. It functions best under wet and dry conditions and, while good under constant immersion in water, is not outstanding.

b. It must be applied over a perfectly clean steel surface because organic contaminants will prevent adhesion.

Physical and chemical properties of the zinc silicates are roughly a composite of the properties of hot dipped galvanizing and a fused ceramic. Even prior to curing, the films will withstand the fairly rough handling encountered with steel handling equipment without the necessity of observing any special precautions, except that the film be dry. It is customary to handle such coated items with bare wire lines and chains.

Compare Favorably with Organics

Thoroughly cured films have a very high order of adhesion and abrasion resistance substantially better than those of the usual organic coatings. Being metallic, they do not have a high order of flexibility; however, they are sufficiently flexible to follow the normal expansion and contraction of steel surfaces.

Because the materials contain zinc pigment in a silicate binder, they are not particularly suitable for services involving very low or very high pH environments. Acids attack the zinc pigment. Concentrated alkaline solutions, such as sodium and potassium hydroxide, destroy the matrix. It should be emphasized that the chemical resistance of the film is substantially superior to that of pure zinc alone, as found in galvanizing. Much of the zinc pigment in the coating is shielded by the inert silicate matrix.

Zinc silicates should be applied over a freshly sandblasted surface. Most coating manufacturers and users recommend a white metal blast, and this is certainly the optimum. This surface preparation specification has lead to a general feeling in industry that zinc silicates can not tolerate as many errors in surface preparation as other generic types of coatings, but this is hardly the case. When surface preparation is considered in the

(Continued on Page 28)

Internal Cleaning –

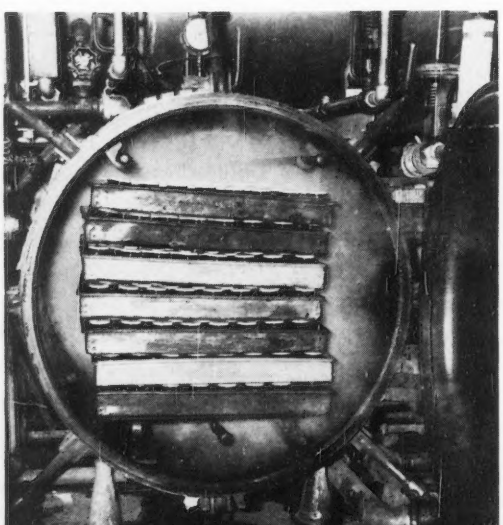
(Continued From Page 20)

presented as a supplement to the paper, film thicknesses ranging from 0.004 to 0.15 inches were inspected from samples of actual field operations. These clearly indicate that on the coatings examined there is excellent homogeneity and no air bubbles, entrapped solvents or pinholding on film thicknesses accurately measured to 0.015 mils in thickness.

Were there some special requirement to install films to 0.025 to 0.030 inches thick, it is the author's opinion, based upon experience, that no special difficulties would be encountered in producing results equal to the best shown in the photomacrographs. Special care would be used in selection of a high solids material which would use a solvent system specified for the job by the author's company. Then on field operations, by carefully trowelling on the material to the desired thickness and regulating the rate of release of the solvents, a good cure showing no significant bubbles and having uniformity of film density and thickness could be readily effected.

Miniature Radio for Paging

A miniature radio for indoor and outdoor voice paging to reach key personnel has been developed by General Electric. It weighs only 12 ounces with battery and has a directive horn that can be clipped to the wearer's lapel. Neither the radio unit nor the horn has to be held to the ear to hear the message. An ear piece can be used when the wearer does not wish to disturb persons around him.



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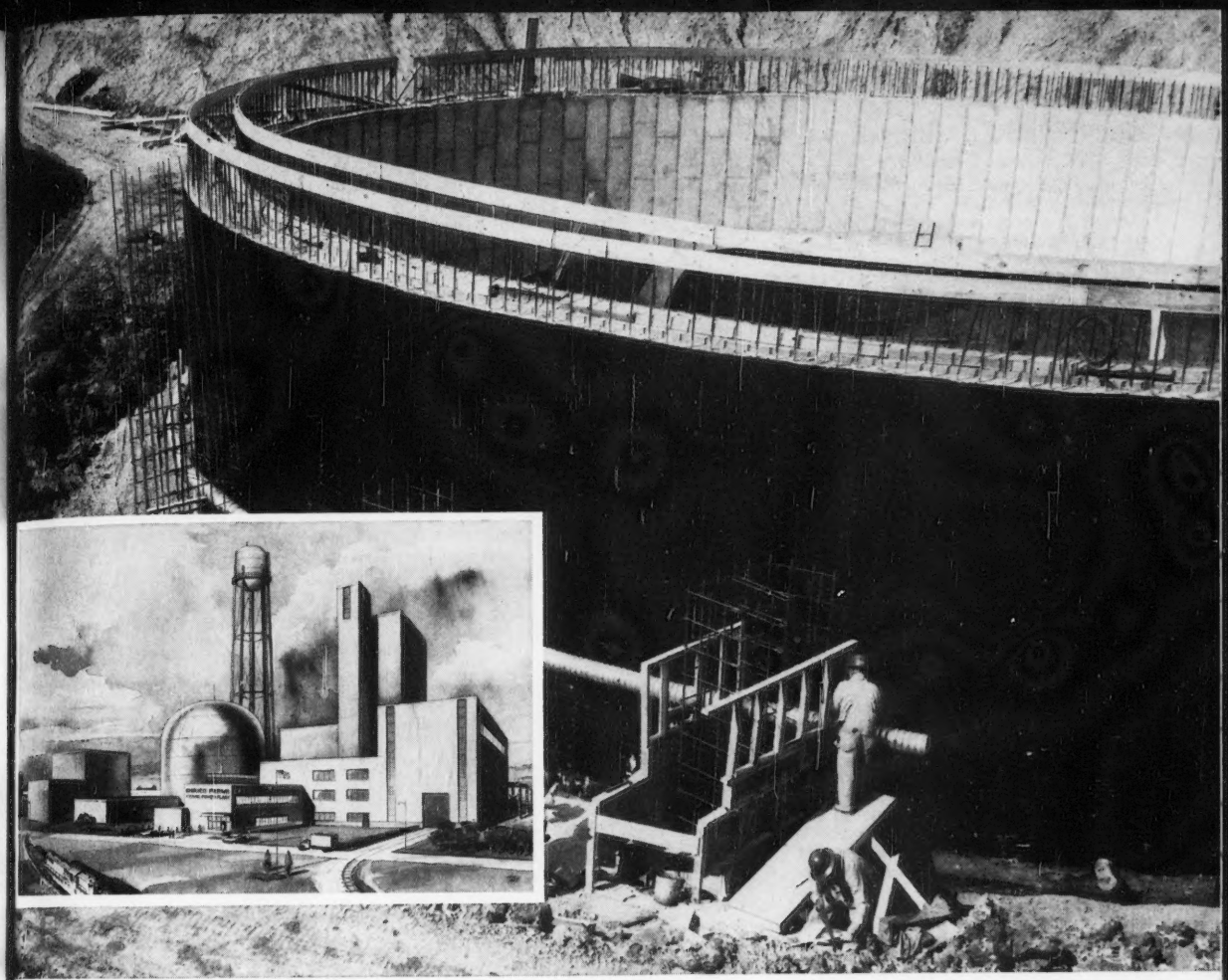

Bitumastic No. 50 waterproofs and protects concrete foundations at atomic power plant

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Nearly 40% of the 915-acre atomic power plant site at Monroe, Michigan, was originally marsh land or entirely submerged before a gigantic filling operation was undertaken. This subsurface condition made damp-proofing of reinforced concrete foundations—particularly of the reactor building, shown under construction, above—an important design consideration. Bitumastic No. 50, well-known for its resistance to water penetration, was applied in two coatings to all concrete foundations.

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Zinc-Filled Coatings—

(Continued From Page 26)

broad sense to include not only sandblasting but grinding welds to a smooth contour and removing weld splatter, the zinc silicates are perhaps the least sensitive of all protective coatings. The materials are unexcelled in their ability to cling to points and sharp edges and provide long term protection.

Resist Undersurface Corrosion

One of the distinguishing features of the inorganic coatings is their ability to resist undersurface corrosion. This property undoubtedly results from their tenacious adhesion and tough metallic film. Holidays resulting from misapplication, severe abrasion or destruction of the film in areas due to spillage of strong acid solutions, remain the same size over a period of years, and if small enough, receive cathodic protection from adjacent areas of the film to prevent pitting.

A good example of this is an area of structural steel in the Union Carbide Chemicals plant at Texas City, Texas. This area was coated with a zinc silicate coating approximately six years ago by workmen who had no previous experience whatever with the application of the material. There were many holidays in the film and many other areas where the material was applied so thickly that it spalled from the surface. While the area is unsightly, no pitting of the steel has occurred in the holidays despite its location in a very corrosive, coastal atmosphere laden with organic and inorganic chemical fumes. This is thought to be a tremendously important feature of the material, particularly when used on steel which will not be readily available for maintenance work due either to enclosure or positioning adjacent to sensitive instrumentation and/or operating equipment.

These properties make the zinc silicate especially suitable as a protective coating for steel to be subjected to long storage or to overseas shipments. Abrasion resistance of the film permits using the coating to advantage as a "shop primer." It is not uncommon to find in coastal areas properly applied inorganic zinc coatings which have been in service eight to ten years and display no deterioration whatever.

Coatings Are Self-Policing

Unlike organic coatings, the inorganic zinc silicates are to a large degree self-policing. If they are applied over old paint, mill scale, or an oily surface, they release immediately. If they are applied at too great a film thickness, they will mud-crack or spall from the surface almost immediately. About the only application error which can go undetected for a period of time is thin film. This may exhibit itself as a light rust "bloom" corresponding to oxidation of the peaks of the anchor pattern. While repair is simple, and consists of nothing more than cleaning the area with emery paper or wire brush and building up the film to the prescribed thickness, the necessity for remedial work can be eliminated by applying a minimum film thickness of 2½ mils.

In addition to film thickness, two other tests are commonly made by operators in the field to check on the quality of their work. The first consists of keeping an area wet with water for a period and checking the film for softening. One method for accomplishing this consists of scoring through the coating with a sharp instrument and then covering the scored area with a wet blotter. If no softening has occurred at the end of two to three hours, it can be assumed that the film is cured. A second test consists of cutting the film with a sharp instrument such as a knife. If the material cuts to a clean edge without exposing any powdery material at the interface or any brittleness, it can be assumed to be cured.

A large segment of industry has accepted the zinc-silicate coatings as a standard for lining both marine and shore based tanks for services involving alcohols, esters, nitroparaffins, dry chlorinated hydrocarbons, ketones, aviation gasoline, jet fuel, housebrand gasoline, stove oil, crude oil and aromatics such as benzene, toluene, and styrene.

Leaching Not Observed

Within the limits of present analytical procedures, no evidence has been found that any component of the zinc-silicate film is leached from the film by any of the commodities listed above. On marine tankage, zinc-silicate coatings have the ability to prevent metal loss over a period of years when transporting the listed commodities in tanks ballasted alternately with sea water.

Figure 2—This is the result of underfilm corrosion. Note the heavy loss in steel.

The zinc silicates display two other properties which certainly distinguish them from all organic coatings. These properties are their resistance to severe weathering conditions and sunlight, and their ability to serve as a permanent prime under chemically resistant organic topcoatings.

As a permanent primer, metal inorganics offer some outstanding advantages, particularly for maintenance work in the chemical industry. Here it is a common practice to overcoat them with resistant vinyl or epoxy topcoatings. When moisture vapor penetrates the topcoats, no metal loss results due to the barrier and cathodic action provided by the zinc silicate. While organic primers with effective inhibitors give limited protection to the surface, they lack the life expectancy of the zinc silicates and their ability to prevent undersurface corrosion. In an aggressive environment, organic primers soon permit the formation of iron corrosion products. These hard, voluminous materials have a prying action on the topcoats. The zinc silicate provides a barrier over the reactive steel surface preventing such a reaction under an organic coating. In most environments the use of inorganics as a permanent prime will at least double and may quadruple the life expectancy of any organic coating system.

Utilization of the inorganic zinc as part of a protective coating system represents an economical approach to long lasting steel protection in corrosive atmospheres, even strong acidic environments. Properly protected by a resistant top coat system, the maintenance costs are reduced so much that the cost per square foot per year is much less than for a cheaper system. As long as the zinc is protected, costly surface preparation need not be met in the future.

Overcoating Problem Possible

Under some conditions overcoating can present a problem, because the curing solution leaves a waxy residue on the surface of zinc-silicate coatings. Further, the zinc reacts with carbon dioxide in the atmosphere to form a basic zinc carbonate on the surface of the film. This can cause loss of adhesion with some types of topcoats, particularly oil base paints.

These problems can be avoided by proper scheduling and selection of overcoats. In coastal areas, four to six weeks of weathering normally will remove all traces of the curing solution residue so that no surface preparation is required prior to topcoating. Some vinyl resin coatings as well as amine and polyamide epoxy coatings adhere tenaciously to zinc silicates without the necessity of special priming. The ultimate in cost economy and effectiveness often can be achieved with one application of a vinyl coating especially formulated for application by airless spray. Pinhole-free organic films of 5 to 7 mils thickness are relatively easy to secure by such a procedure. When circumstances require that the inorganic primer be overcoated immediately, the curing solution residue can be removed by washing the surface with water after 24 hours. Live steam often is used to facilitate cleaning.

Materials Are Versatile

Presently available inorganic coatings and perhaps the newer ones are very versatile materials for the permanent protection of industrial structures. This is especially true in the southern areas of the United States (the Gulf Coast, Florida and the southeast coast) where intense sunlight, continuous high humidity and either sea air or chemical fumes or both create the most severe atmospheric conditions. Whether used alone or as a permanent primer in combination with organic topcoats, these inorganic zinc coatings probably provide the most permanent maintenance coatings available today.

DISCUSSIONS

Question by A. L. Alexander, U. S. Navy Research Laboratory, Washington, D. C.

With reference to test coatings on drums, how do you explain the relatively poor protection on sides as opposed to the tops where moisture should collect and form a more corrosive condition?

(Continued on Page 30)

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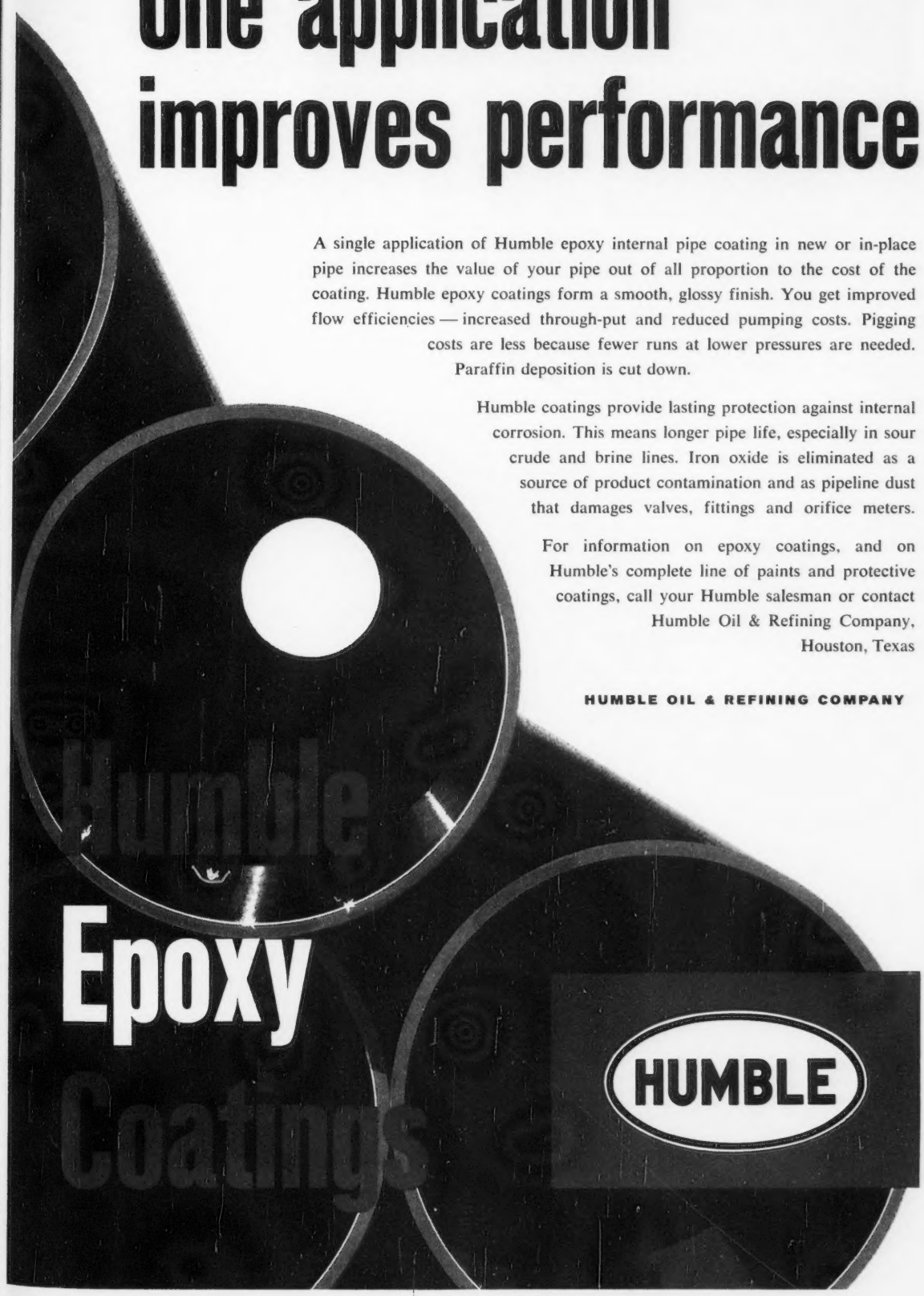

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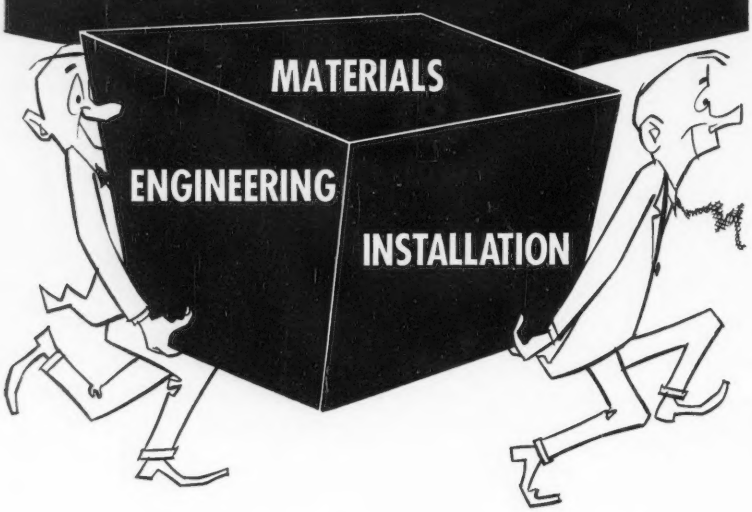

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Zinc-Filled Coatings—

(Continued From Page 28)

Reply by F. Parker Helms:

In test drums shown in the informal presentation, the deliberate holidays were larger on the vertical sides than on the horizontal top so that corrosion appeared to be more severe on the sides. In general and on like tests of organic coatings, severity of corrosion as to top or sides is a function of several variables, two of which could be application thicknesses and turbulent air circulation in test area.

Question by H. F. Haase, Milwaukee, Wisconsin:

What is your experience with inorganic zinc coatings in submerged service?

Reply by F. Parker Helms:

Field experience with inorganic zinc coatings for submerged service is limited; however, there is sufficient experience to conclude that for this service many additional variables are found. Immersion service for liquids other than water are covered in the article. Characteristics of waters are so variable that detailed investigation coupled, if possible, with extensive laboratory and/or field testing is required before recommending any zinc coating for any water immersion service.

Question by Marion D. Garrison, Lake Charles, Louisiana:

Have you had any experience with zinc silicate coating used on atmospheric cooler coils, the type of installation where hot dipped galvanized has often been used? Comment on their relative value.

Reply by F. Parker Helms:

I have no field experience in this matter. An intimate knowledge of the corrosive environment would be required before intelligent speculation could be made as to relative value of either coating. Incidentally, economics also should be considered in selection of one of these coatings for any application.

Question by Alf M. Myhre, E. I. duPont de Nemours & Co., Wilmington, Delaware:

What is your experience with these coatings in services involving temperatures in excess of 300 F?

Reply by F. Parker Helms:

There is not sufficient experience to make any recommendations on utilization of these coatings in hot immersion service. On alternate wet or dry conditions, cooling tower piping experience of approximately five years at temperatures to 345 F indicates satisfactory performance. Extensive experiences of five to six years in hot, dry service indicate satisfactory performance to 600 F; however, atmospheric chemical environment must be considered.

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MAINTENANCE COATINGS WITH EXPERIENCE

Relation of Molecular Structure and Pigments to Coating Performance*

Abstract

A discussion of the main components of coatings, with emphasis on their characteristics related to these components. Molecular structure, significance and function of primary and secondary bonds, relationship of molecular weight to performance are considered. Function of modifiers and how they influence the characteristics of coating is explained. Mechanism of adhesion is reviewed briefly, considering the fundamental mechanical and electrochemical factors involved in this phenomenon. 4.1

GONE FOREVER are the days when red-lead-in-oil primers and bituminous finishes represented the summation of paints for corrosion control. Today many basic types of protective coatings and a multitude of modifications and trade names make coatings selection a complex procedure.

This article is aimed at corrosion engineers who are not paint specialists but who are acquainted with paints and their properties. General properties of paints that corrosion engineers are interested in are given in Table 1.

An attempt will be made to explain the wide differences in properties found in paints now available. While the title of the article suggests that the differences are related to the molecular structure of the oils and resins, it will be seen that pigments also are important when corrosion inhibition is considered. When special structures are synthesized for some of the new resins, the cost usually is more than for the simpler structures provided by Nature.

Constituents of Paint

Paint consists essentially of four components: pigments, oils or resins, volatile solvents and driers or catalysts. Pigments are finely powdered solids that provide color, opacity and in some cases corrosion inhibiting properties. Oils or resins are used to bind the pigment particles into a coherent coating, hence they are referred to as "binders." Volatile solvents reduce consistency so that the paint may be brushed or sprayed properly. Driers or catalysts are added in small percentages to some coatings to accelerate drying time. A list of the principal binders used in paint will be found in Table 2.

Binders in Table 2 are divided into three groups because coatings made from them solidify by three different methods. The first group dries by oxidation, and the reaction of oxygen from the air with the coating is accelerated by metallic driers such as lead and cobalt soaps. The second group is converted to the dry stage by a chemical reaction that is accelerated by organic catalysts such as polyamines. The third group dries by evaporation of the solvent.

Nature of Molecules

To understand the relationship between molecular structure and coating performance, it is necessary to consider what happens when a liquid coating dries or is converted to solid state. For example, why do the binders in Group 3 become dry and hard by simple evaporation of the solvent while the other two groups require either oxidation or another type of chemical reaction after the solvent has evaporated?

The answer lies chiefly in the size and reactivity of the molecules. The molecules of Group 3 have molecular weights ranging from 20,000 to 500,000 while those in Groups 1 and 2 range from less than 1000 to not more than 5000. Small molecules are not large enough to make strong solid materials; therefore they are connected together by chemical bonds and other association forces to make large molecules which are strong solids.

The size of a molecule will affect its physical state and largely determines whether it is a gas, a liquid, or a solid. Four well known materials in Table 3 illustrate the effect of molecular size or weight on their properties.

The reason for this difference in behavior related to molecular weight is simple and involves the kinetic energy of molecules and the association forces between them. Under normal temperatures and atmospheric pressure the kinetic energy of the small methane molecules is so large compared to their weight that they bounce around in all directions with practically no association forces among them. This condition is characteristic of a gas.

The larger pentane molecules are too heavy to bounce around so they associate with one another more closely to form a liquid. However, the association forces are not strong enough to prevent the molecules from flowing or sliding past one another. This is characteristic of liquids.

When the molecular weight is increased to 282 as in paraffin wax, the kinetic energy is low compared to the weight, and the association forces between the molecules are now large enough to prevent the movement of individual molecules so the material is a rigid solid. However, paraffin wax is a very weak solid compared to the high molecular weight polyethylene, which shows that the association forces be-

(Continued on Page 34)

★ Revision of a paper titled "Molecular Structure and Coating Performance" by Henry F. Payne, College of Engineering, University of Florida, Gainesville, presented at a short course on corrosion sponsored by the Miami and Jacksonville Sections, National Association of Corrosion Engineers, November 16-20, 1959, Miami, Fla.

TABLE 1—Properties of Corrosion Inhibiting Paints

1. Rate at which paint dries.
2. Hardness, flexibility, and toughness of coating.
3. Adhesion to metals.
4. Resistance to water, solvents, and chemicals.
5. Ability to inhibit corrosion.
6. Cost per sq. ft. per year of service.

TABLE 2—Binders for Organic Coatings

Group 1	Group 2	Group 3
Drying Oils	Rubbers	Bitumins
Varnishes	Epoxy resins	Rubber resins
Alkyds	Epoxy-Polyamides	Chlorinated rubber
Epoxy esters	Polyesters	Vinyl resins
Urethane Oils	Urethanes	Lacquers

TABLE 3—Properties vs Molecular Weight of Non-Polar Compounds

Formula	Compound		Mol. Wt.
CH_4	Methane	Gas	16
C_5H_{12}	Pentane	Liquid	72
$C_{20}H_{42}$	Paraffin wax	Weak solid	282
$C_{2000}H_{4002}$	Polyethylene	Strong solid	28,000

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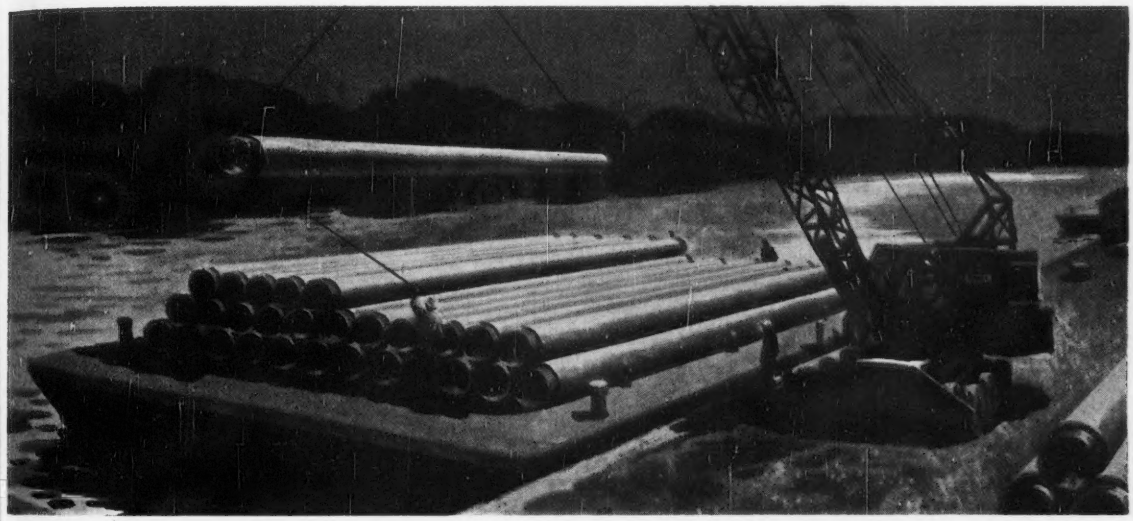

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Coating Performance –

(Continued From Page 32)

tween the molecules increase with the molecular weight.

However, the situation is not quite as simple as indicated, so look at another series of compounds which also increase in molecular weight. Generally they change from gas, to liquid, and to solid as the molecular weights increase but the change is more rapid.

Types of Binding Forces

The compounds in Table 4 change from gas to solid with much smaller increase in molecular weight than do the compounds in Table 3. The difference in behavior of the two types of compounds is due to the difference in strength of the association forces between their molecules. Note that Table 3 compounds are called non-polar whereas those in Table 4 are polar compounds. The association forces between molecules of polar compounds always are stronger than those between non-polar compounds of comparable molecular weight.

Forces which bind atoms into molecules and molecules into organic materials are of two types called primary and secondary bonds. Primary bonds result from direct chemical reaction and they are very strong. Secondary bonds are much weaker and are due to electrostatic forces between molecules. Association forces, the secondary bonds, vary from quite weak to fairly strong depending on the relative polarity and molecular weight of the molecules.

Molecules consist of a group of atoms bound together by primary bonds. For example, the first compound in Table 4 consists of two atoms of carbon and six atoms of hydrogen chemically bonded into a unit which will maintain its identity as ethane. It can be destroyed by temperatures which are high enough to break the primary bonds between the atoms but it is strong enough to maintain its identity under conditions such as distillation.

Atom Content Is Criterion

Formulas in Tables 3 and 4 show that molecules vary greatly in the number and kinds of atoms they contain. Differences in properties of materials depend not only on the number and kind of atoms in their molecules but also on the structural arrangement of the atoms. Builders can construct many kinds and sizes of buildings from a pile of bricks; each kind of building designed for specific uses. Similarly, organic chemists can synthesize different molecular structures from atoms such as carbon, hydrogen, oxygen, nitrogen and sulfur. Even if only carbon and hydrogen atoms are used, such as the compounds in Table 3, the properties vary considerably with the number and arrangement of these atoms in the molecules.

Solid materials consist of aggregates of molecules bound together with primary bonds, secondary bonds, or a combination of these forces. If there are a great many primary bonds in the molecular aggregates, the material will be very strong and resistant but it may be so hard that it will be brittle. In the development of new resins one major problem is to compromise between sufficient primary bonds for hardness and resistance without sacrificing flexibility.

If molecular aggregates are held together by secondary bonds, the material will be weak unless the molecular weight is quite large. Binders in Group 3, Table 2 have only secondary bonds in the molecular aggregates but are strong and tough materials because they have high molecular weight. Secondary bonds are forces in the surface of molecules; therefore the total force will be large if the molecules are large. The weakest material of Group 3 is the bitumins which have relatively low molecular weight.

TABLE 4—Properties vs Molecular Weight of Polar Compounds

Formula	Compound	Properties	Mol. Wt.
C_2H_6	Ethane	B.P. 86 C Gas	20
C_2H_5OH	Ethyl Alcohol	B.P. 78 C Liquid	46
$C_{11}H_3COOH$	Acetic Acid	B.P. 118 C Liquid	74
$(COOH)_2$	Oxalic Acid	M.P. 187 C Solid	114

Solvents Attack Bonds

All binders in Group 3 are sensitive to attack by solvents and the bitumins are the most sensitive of the group. Solvents can overcome the secondary bonds and break down the aggregates, particularly if the molecular weight is not large. By comparison, the binders in Groups 1 and 2 make coatings which are resistant to solvents because their molecular aggregates are bound with primary bonds. However, there is considerable difference in solvent resistance of these coatings because some of the binders have more reactive locations at which primary bonds may be formed. While the least resistant coating in two groups may not dissolve, it may swell so much that the coating loses its protective value. This reasoning suggests that oils or resins might be added to the bitumins to increase their solvent resistance. Special blends of coal tars and epoxy resins cured by amine catalysts for example, produce coatings having excellent resistance to water, solvents and chemicals.

Nitrocellulose lacquers are not used extensively in corrosion resistant coatings, but they make excellent finishes for furniture. Since their molecules are bound together only by secondary bonds, lacquers are sensitive to solvents. This was a difficult problem until it was realized that blends could be made with nitrocellulose and epoxy resins, or mixtures of epoxy and amino resins, which introduce primary bonds between the molecules with consequent resistance to solvents.

Catalysts Increase Bonds

Those familiar with the difference in rate of drying of the materials in Groups 1 and 2 know that Group 2 materials solidify very much faster than those in Group 1. In fact, Group 2 materials are so reactive they usually are shipped in two-package containers to be mixed just before using. Also, Group 2 materials are more resistant to solvents and chemicals than those in Group 1. It will be apparent that Group 2 materials consist of relatively small molecules before appli-

(Continued on Page 37)

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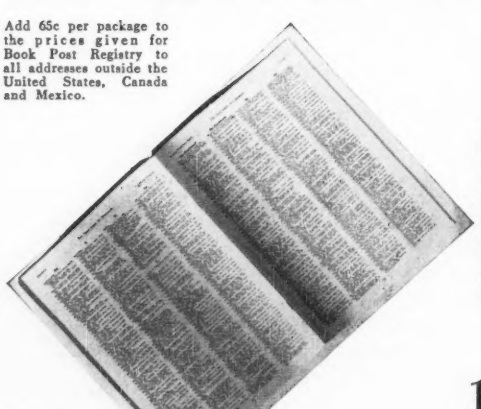

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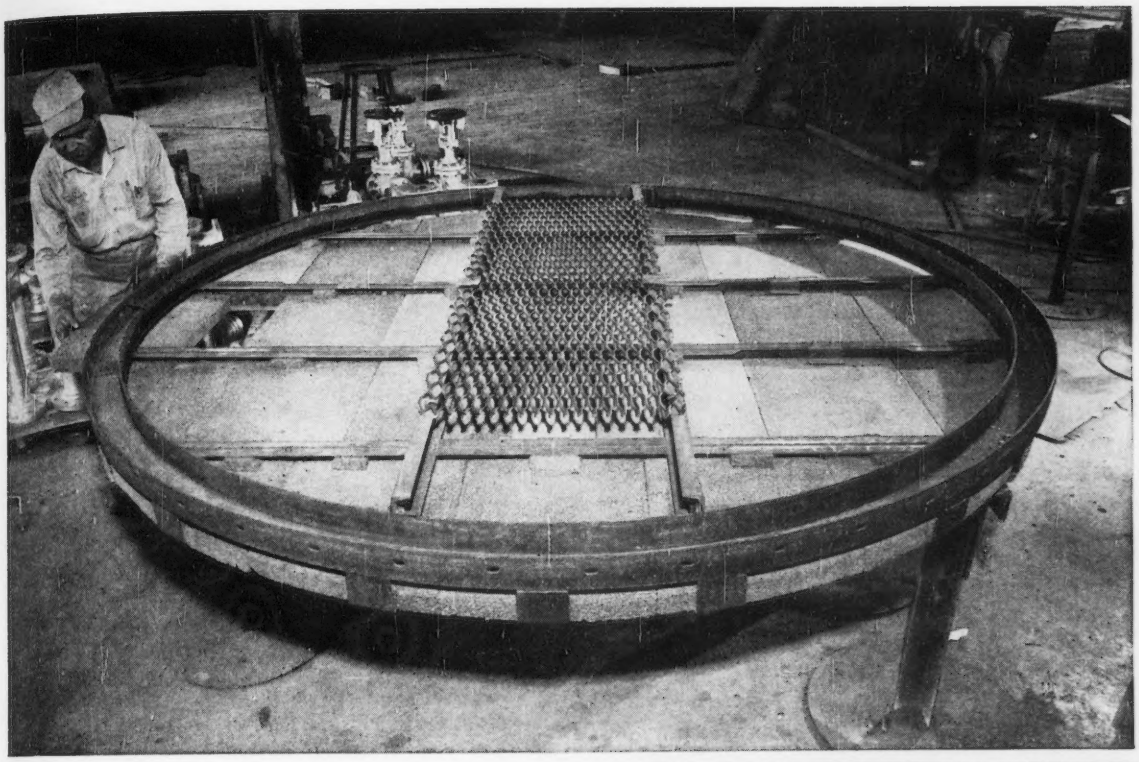

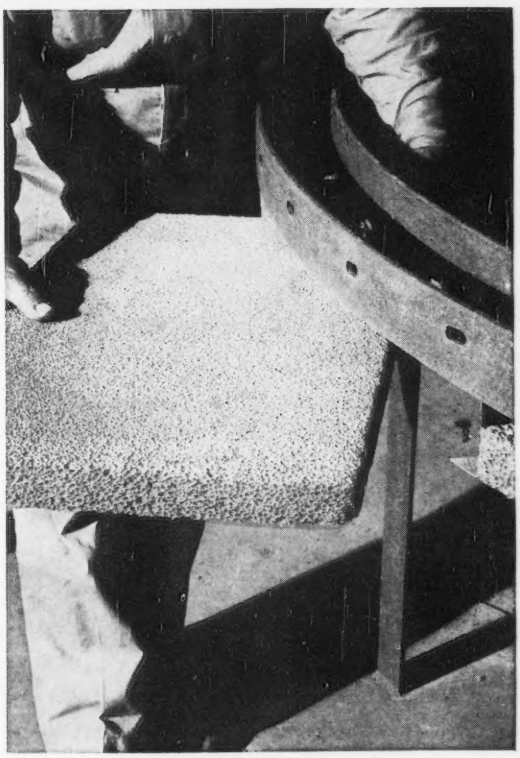

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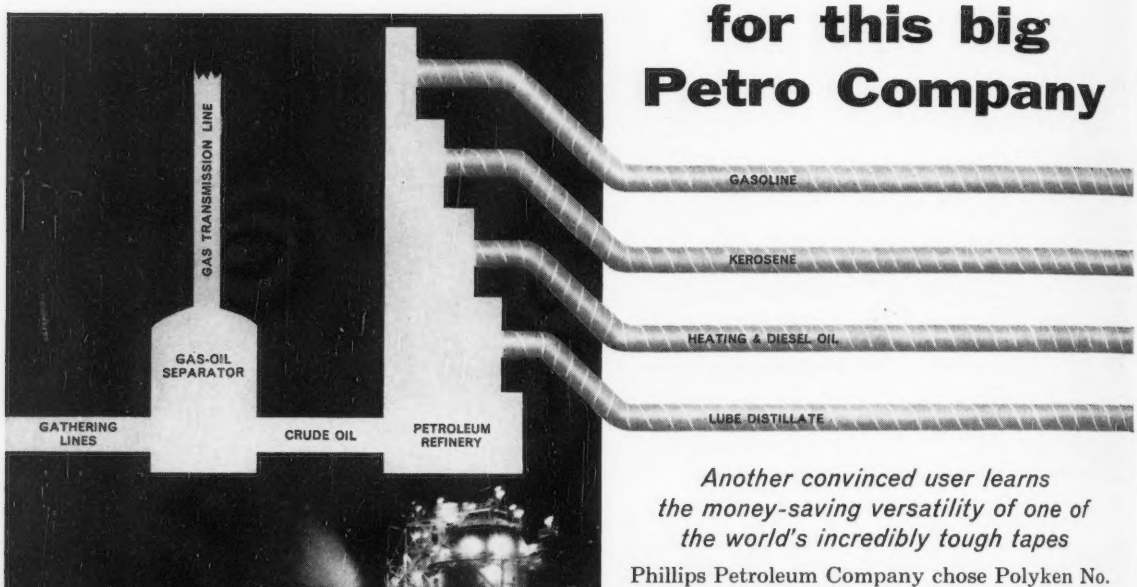

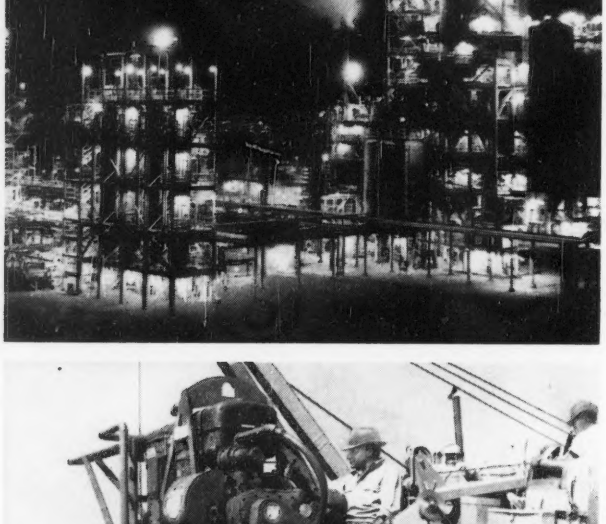

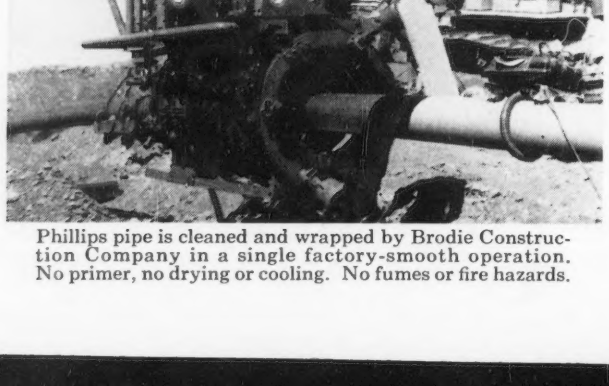

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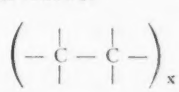
Coating Performance –

(Continued From Page 34)

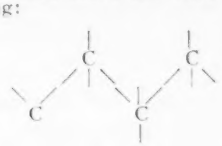
cation which are cured by the catalyst or react with one another to form many primary bonds in the molecular structure of the finished coating.

Materials in Group 1 solidify by oxidation, which is a slow process compared with the reactions in Group 2. Furthermore, because the required oxygen is obtained from the air, these coatings tend to dry first on the surface and then continue to dry more slowly underneath. This continued drying may lead to embrittlement on aging which is most pronounced with coatings based on drying oils such as linseed. However, when drying oils are combined with other resinous compounds to form varnishes, alkyds, epoxy esters, or urethane oils, the oil component becomes decreasingly less; therefore less oxidation is required and the coatings cure faster and have better durability. The molecular structure of these coatings can be drawn on paper, or built with molecular models, and the performance of the coatings can be predicted quite accurately.

Hardness is indicated by the number and arrangement of primary bonds in the molecular aggregates and by high molecular weight of binders that have secondary bonds. Now consider materials such as polyethylene, polyvinylacetate, and the acrylic polymers which have good surface hardness and toughness but also are very flexible. These materials would be classified under vinyl resins in Group 3, therefore they have high molecular weight and secondary bonds between their molecules. They often are referred to as straight chain polymers with a carbon-carbon backbone and side groups along the chain. Frequently their molecular structures are indicated as follows:



The number represented by "x" indicates the length of the carbon chain. The short lines above and below each carbon atom mean that an atom of hydrogen or another group of atoms is attached to the carbon. The term straight chain polymers is misleading on two counts. Firstly, the actual configuration is not that indicated above but more like the following:



Secondly, the polymer chains do not lie along side one another in straight lines but are all mixed and intertwined like a heap of wriggling snakes. When one of these flexible materials is stretched the long molecules uncoil. If stretched sufficiently, they align themselves as closely as possible. This condition presents the maximum surface of each molecule to the others and thus develops the maximum strength from the secondary bonds. Stretching beyond this point will overcome the secondary bonds and the material will become thinner and finally break. Breaking always is due to failure of the secondary bonds between the molecules and not to the primary bonds in the molecules.

What Makes Materials Rigid

Another important characteristic which contributes to flexibility is the ability of carbon atoms to rotate freely about the axis of the bond between them. This means that considerable bending or twisting of the molecular chains can occur. However, rotation can be decreased and even prevented if there are side groups of atoms along the chain that block the twisting movement. All are familiar with the marked difference between polyethylene and polystyrene. The first is very flexible and the second is a rigid plastic. These materials are identical in molecular structure with the exception that polystyrene has a side group of atoms on every other carbon in the chain. This group not only prevents rotation but also the sliding of chains past one another.

How Plasticizers Function

Why does the addition of a plasticizer to high polymers such as the vinyl resins increase flexibility? Plasticizers are small molecules dispersed among the chains of the polymers. They separate the chains slightly, prevent development of maximum strength from the secondary bonds and always decrease tensile strength. They permit the chains to uncoil and move about more freely, thus imparting flexibility.

Corrosion resistant coatings usually are applied to bare metals which have fairly smooth surfaces. Why is it that there is no question about the adhesion of some coatings but others require special primers or mechanical roughening of the metal surface such as sand blasting? The answer to this question lies in the nature of adhesion. There are two components in the force of adhesion of a coating to a surface; one is mechanical and the other specific. Mechanical adhesion is easy to visualize. It is fairly obvious that a material can become mechanically attached to a very rough surface easier than to a very smooth surface.

**TURN TO PAGE 135
for
ANOTHER ARTICLE
on
COATINGS
"Industrial
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Molecular Structure Significance

Specific adhesion is more difficult to visualize because it is related to the molecular structure of two materials (substrate and coating) and particularly to their relative polarity. Does water adhere to wax? No, because water is a highly polar compound and wax is non-polar. The specific adhesion between water and wax is practically zero. Water adheres readily to wood, paper, or cotton fabrics because these are highly polar materials but water does not wet the practically non-polar synthetic fibers.

Water will not wet metals that have non-polar grease on them but will wet clean metals fairly well. Metals are not as strongly polar as wood or paper and

(Continued on Page 38)

Coating Performance—

(Continued From Page 37)

most organic coatings wet metals better than water does because coatings are not as strongly polar as water.

Another factor must be considered for coatings which have poor adhesion. This factor is the molecular cohesion of the coating versus the molecular adhesion to the metal. Coatings which have very large molecules with strong forces between them exhibit great cohesive strength. This is desirable because it makes the coatings extremely tough. However, the internal cohesion may be greater than the specific adhesion to smooth metal. This difficulty can be overcome by increasing the mechanical adhesion by changing the profile of the substrate through sand blasting, or by changing the molecular structure to increase specific adhesion.

How Modification Helps

The polyvinylchloride-acetate copolymer resins provide an interesting example of modifying the molecular structure to change the adhesion characteristics. One of the most widely used of the vinyl resins has excellent properties, has good adhesion to metal if the coatings are baked at 350 F, but will not adhere if it is air dried. When molecular structure of this vinyl resin is modified to include about 1 percent of an organic acid which contains the highly polar carboxyl group, the adhesion is changed so greatly that coatings made with the modified resin will adhere to metal when air dried.

Although it may seem that this simple expedient can be applied generally, this is not the case. Introduction of the highly polar carboxyl group increases the affinity of this resin for water because materials of similar polarity attract each other. Where maximum resistance to water is required the modified vinyl resin is not as good as the original resin.

Another illustration of this effect is a comparison of polyethylene and polyvinylalcohol. Both materials make very strong coatings and whereas polyethylene is very resistant to water the polyvinylalcohol coating can be dissolved by water. The molecular structures of these two materials are very similar but a non-polar hydrogen atom on every other carbon atom in the polyethylene structure is replaced with a very polar hydroxyl group to produce polyvinylalcohol. This change of structure from non-polar polyethylene to polar polyvinylalcohol changes some of its performance characteristics radically.

Chemical Resistance Related

Chemical resistance also is indicated by the molecular structure. It is well known that esters react with alkalies to form soaps, so if there are ester groups in the molecular structure, low resistance to alkali may be expected. Drying oils and alkyd resins have ester groups as a prominent part of their structure. If coatings of these materials are subjected to alkali solutions, reaction with the ester groups takes place and the structure is broken down. By comparison a true epoxy resin does not contain ester groups and its coatings have excellent resistance to alkali.

From this very brief outline of the effect of molecular structure on the performance of coatings it will be realized that knowledge of this type can be very helpful to corrosion engineers who have to contend with the many new types of coating now available. Additional information is available in standard books on physical and organic chemistry, but usually these are quite generalized and not specific for coatings. Some books are specific, however.[1] Much research is being done in this field which may produce new coating materials. An understanding of the relationships between structure and performance will contribute to ability to use new coating materials to best advantage.

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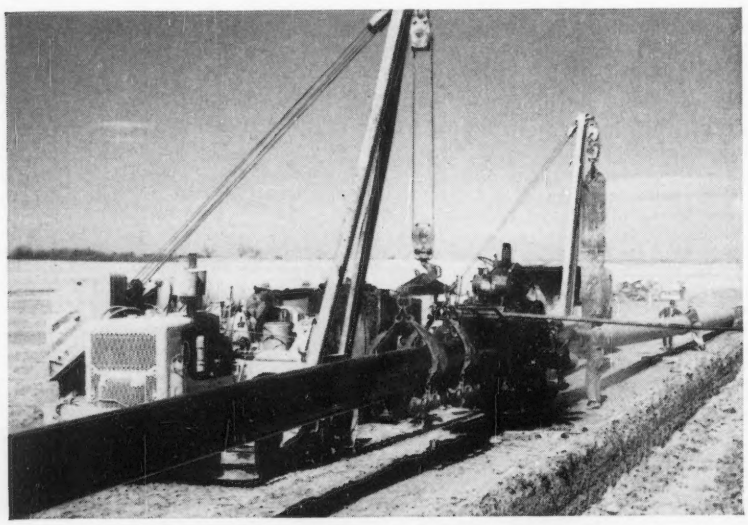

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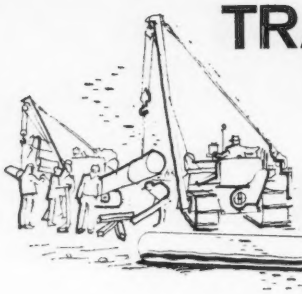

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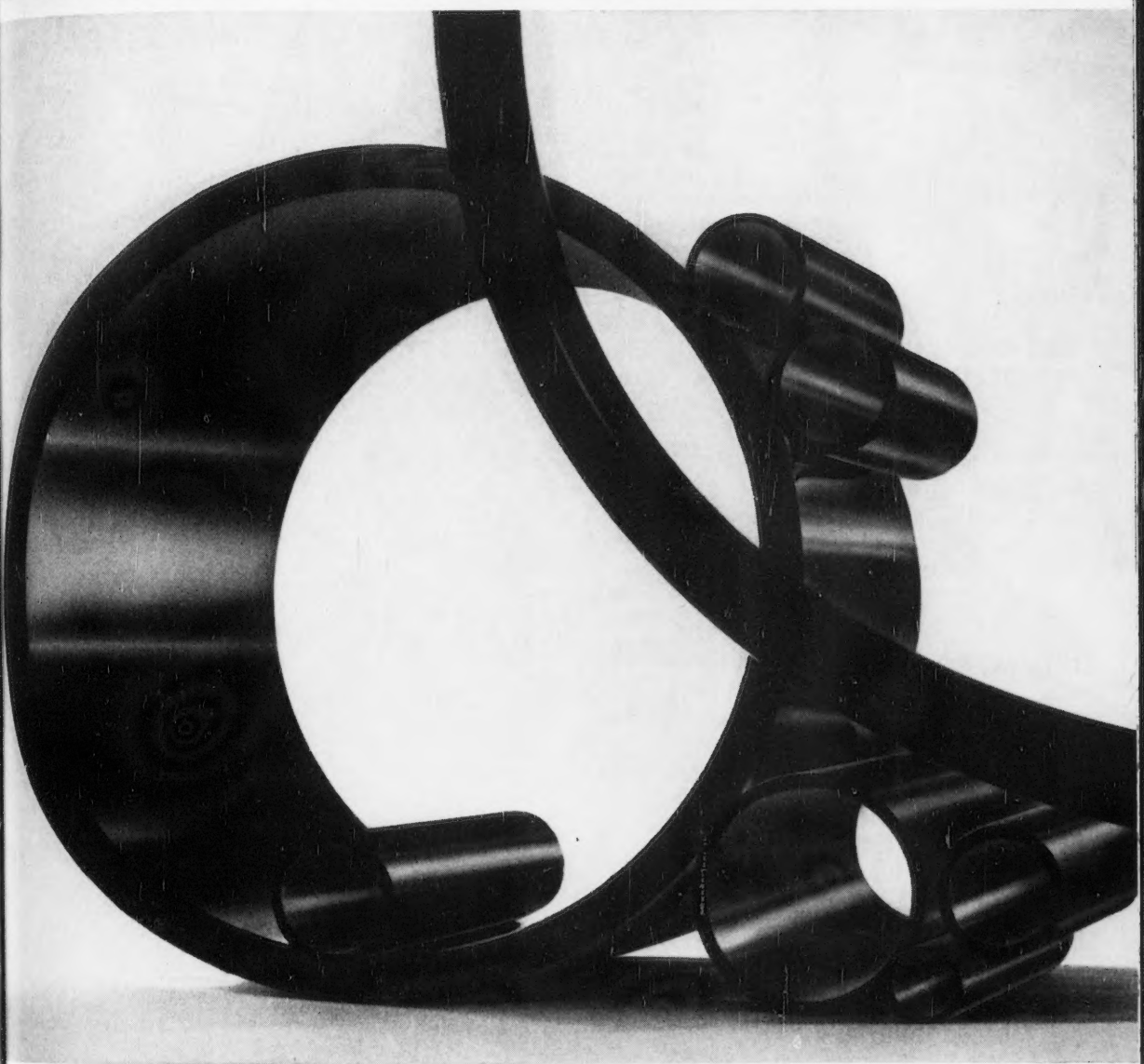

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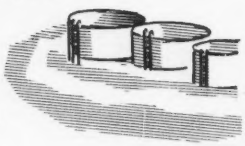

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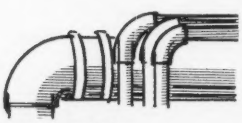

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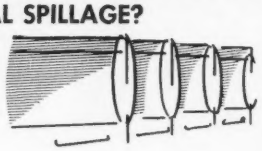

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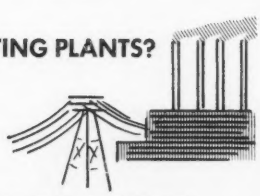

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Plastics' Generic, Trade Names And Manufacturers Tabulated

Generic names for 44 plastic materials are listed below with their trade name and name of the manufacturer. This list is not comprehensive size; it represents those plastic names which the editors of CORROSION have encountered during the past two years.

Persons or companies wishing to add other trade names, generic terms and manufacturers for publication in a similar table at a later date should submit this material to Dale Miller, CORROSION Magazine, 1061 M & M Bldg., Houston 2, Texas.

PLASTICS TABLE

Trade Name	Generic Name	Manufacturer
Ace-Ite	Polystyrene copolymer	American Hard Rubber
Ace Parian	Polyethylene	American Hard Rubber
Ace Riviclor	Polyvinyl chloride	American Hard Rubber
Acrilan	Polyacrylonitrile	Chemstrand Corp.
Atlas 352	Polyester	Atlas Powder Co.
Butyl A and B	Isobutene-isoprene	Enjay Co., Inc.
Delrin	Acetal resin polymer	du Pont
Durez	Phenol formaldehyde	Hooker Electrochemical
Dynel	Vinylchloride acrylonitrile	Carbide & Carbon Chemical
Estane VC	Polyurethane	B. F. Goodrich
Fairprene	Polychloroprene	du Pont
Fluoroethene	Polychlorotrifluoroethylere	Carbide & Carbon Chemical
Fluoroflex T	Polytetrafluoroethylene	Resistoflex Corp.
Formica	Urea resins	Formica Insulation Co.
Genetron	Polytrifluorochloroethylene	
Geon	Polyvinyl chloride, rigid	B. F. Goodrich
Haveg	Phenolic resins	Haveg Corp.
Hycar	Butadiene-styrene rubber	B. F. Goodrich
Hypalon	Chlorosulfonated polyethylene	du Pont
Kel-F	Polychlorotrifluoroethylene	Minnesota Mining & Mfg.
Koroseal	Polyvinyl chloride, rigid	B. F. Goodrich
Kralastic	Polyvinyl chloride	Kraloy Plastic Pipe Co.
LS-53	Fluorosilicon	Dow Corning
Lucite	Polymethylmethacrylate	du Pont
Moplen	Polyolefin	Montecatini (Italy)
Mylar	Polyester, saturated	du Pont
Neoprene	Polychloroprene	du Pont
Orlon	Polyacrylonitrile	du Pont
Oxiron Resins	Polyolefins, epoxidized	Food Machinery & Chemical
Parlon	Chlorinated rubber	Hercules Powder Co.
Penton	Polybichloromethyl oxetane	Hercules Powder Co.
Petrothene	Polyethylene resin	U. S. Industrial Chemicals
Plaskon	Urea resin	Plaskon Co., Inc.
Plexiglas	Polymethylmethacrylate	Rohm & Haas
Rexolite	Constant styrene copolymer	
Saran	Vinylidenechloride vinylchloride	Dow Chemical Co.
Silastic	Silicon rubber	Dow Corning Corp.
Synthane	Reinforced phenol formaldehyde	
Teflon	Polytetrafluoroethylene	du Pont
Tenite	Cellulose acetate	Tennessee Eastman Corp.
Thiokol	Polysulfide	Thiokol Corp.
Tygon	Furfural resin	U. S. Stoneware
Vinylite V	Vinylchloride vinyl-acetate	Bakelite Corp.
Viton A	Hexafluoropropylene-vinylidene fluoride	du Pont

WOOD-STAVE PIPE LINE with a life expectancy of 50 years or longer has been constructed to deliver water from the Victoria Falls Dam to the hydro-electric generator station of Upper Peninsula Power Company, Rockland, Mich. Kiln dried, pressure creosoted Douglas Fir was chosen for fabrication of the 10-foot, 2-inch inside diameter pipe which is over one mile in length. This construction was a replacement of an older wood pipeline which had been in service almost 30 years. Original round steel bands connected with malleable iron shoes and many original concrete cradles and sill foundations were re-used in the new pipeline (shown in top photograph). The staves were finished 3½ inchs thick and 5½ inches wide with 72 staves to the circle. They were fabricated with a specially designed malleable iron casting between stave ends to insure water-tight joints (see bottom photograph). Fabrication and construction were by Simpson Engineered Wood Products Co., 2301 N. Columbia Blvd., Portland, Ore.

RECORD and REPORT

Navy Develops New Coating to Solve Columbium Oxidation

Encouraging results have been obtained in experiments to overcome columbium's poor oxidation resistance. Columbium has come into increasingly important use in nuclear reactors, jet engines and other high temperature applications. Extensive research has been conducted to provide this metal with a self-healing coating.

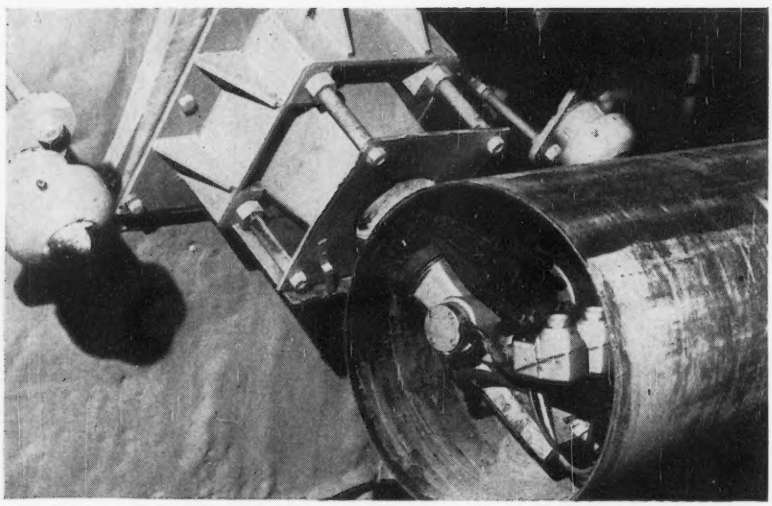
The U. S. Naval Research Laboratory has developed a coating to meet the two requirements for a columbium coating: (1) provide protection against oxidation and (2) have quality of repairing (over temperature range to be experienced by the coated object) any cracks or flaws initially present in coating or which might be expected to form because of mechanical or thermal strain in service.

This new coating consists of layers of intermetallic zinc-columbium compounds on the surface of the columbium. The zinc-columbium intermediate phases are hard and brittle and are readily cracked by mechanical strain or by thermal shock, but they are anchored securely to the columbium substrate and do not tend to spall.

Such a coating produced from unalloyed zinc and unalloyed columbium provides protection against influx of oxygen for several hundred hours at 1800 F and for a few days to a few hours at 2000 to 2200 F in still air.

The Naval Laboratory's research on the coating was reported in an article by C. Sandoz in the April issue of "Journal of Metals," publication of the AIME Metallurgical Society.

Continuous Fluoroscoping Process Developed



X-RAY HEAD of a continuous fluoroscoping inspection unit shown inside a section of welded steel pipe. A fluorescent picture of the weld is transmitted to a television screen inside an inspection booth, permitting an inspector to check the entire length of the weld in large diameter pipe. If a flaw is discovered, the inspector can instantly stop the pipe and mark the flaw automatically with a water soluble white paint.

X-Ray, TV System Detects Seam Flaws In Large Size Pipe

A continuous fluoroscoping process which reveals any hidden flaws or defects in welded seams of large diameter steel pipe has been developed by National Tube Division of U. S. Steel Corporation for quality control purposes.

Welds on large diameter, electrically welded pipe are checked by an X-ray head which casts a shadow image of the weld on the fluorescent screen of an image intensifier. (The X-ray head in the large pipe is shown in the photograph.) The image is intensified electronically and picked up by a television camera. The televised picture, greatly enlarged, is viewed on a monitor screen by an inspector.

In operation, 40-foot sections of welded pipe are placed on a carriage which passes in front of the inspection booth. The X-ray head, mounted on a 48-foot boom, fits inside the pipe in line with the welded seam. The image is projected on the fluorescent screen as the pipe is conveyed past the booth.

Inside the booth, the inspector has a control panel by which he positions the pipe and controls its lateral movement. He can stop the carriage instantly for prolonged examination of any portion of the weld. If a flaw is detected, he marks the spot by pressing a button which releases a spray of water soluble white paint on the pipe.

Pipe welds formerly were checked by X-ray, but only the end portions of each pipe section. Even for this limited area, the X-ray inspection, which required placing and developing of photographic film, was much slower.

Refractory Committee Work

ASTM Committee C-8 on Refractories has begun work on development of methods for determining alkali corrosion of glass tank refractories. Studies have been started on static and dynamic tests applicable to erosion of glass tank refractories at the metal line in glass furnaces.

Pakistan's Scientific Progress Described in 1959 Publication

Scientific progress in Pakistan in the 5-year period 1953-58 is described in the Quinquennial Report of the Pakistan Council of Scientific and Industrial Research issued at Karachi in 1959. Beginning with only four research workers in 1953, the staff of the Central Laboratories now numbers over 300 housed in temporary buildings with 50,000 square feet of floor space. Three regional laboratories have been established also.

About 20 new processes have been developed to the point of commercial exploitation and considerable fundamental research has been done besides. Most of the matters considered concern identification and utilization of natural resources in fossil fuels, minerals, foods, drugs, use of wastes, development of insecticides and fertilizers and other like matters.

Some work has been done in pure physics related to theories of the liquid state and intermolecular forces which originated during investigations on the influence of long-chain phenolic compounds and their derivatives on the viscosity of mineral oils used as lubricants.

Full advantage has been taken also of the facilities of universities and research institutions and research schemes relating to industrial development have been financed at a total estimated cost of about Rs eight lakhs.

The council seeks to make its discoveries known to industry by issuing plain language descriptions for the information of private businesses interested. Advertisements also were placed in newspapers inviting applications for exploitation of commercial processes. So far 19 patents have been secured and applied for.

The Pakistan Journal of Scientific and Industrial Research, first issued in January 1958, is a quarterly containing articles of scientific and technical value. The council also acts to encourage dissemination of technical and scientific information, especially as a service to industry. The Pakistan National Scientific and Technical Documentation Center at Karachi, in operation since the summer of 1957, provides documentation service for the nation. These services, besides copies, include translations into English from the main scientific languages.

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The 9th Annual Meeting of the Standards Engineers Society will be held September 26-28 at the Hilton Hotel, Pittsburgh, Pa.

Operation Pig Squeal

Dry Adsorption Units Now Recover By-Products Previously Avoided

Changing economics in the petroleum industry have prompted the recovery of products that previously were passed up either because of their relative worth or the cost of their separation from natural gas.

Literally getting the last squeal from the pig, large dry adsorption units are being used to recover gasoline and bottled gas products such as propane and butane from natural gas. These units extract the by-products without appreciably shrinking the stream of natural gas flowing through pipelines to domestic and industrial consumers.

Such an adsorption unit has been in operation at Grand Cheniere, La. It consists of eight 20-foot towers. Four of these contain some 60,000 pounds of palletized activated carbon which is efficient in trapping the lighter petroleum products such as propane and butanes. The other four towers contain silica gel and activated carbon for adsorption of the heavier natural gasoline fractions (pentanes, hexanes, heptanes and heavier).

Only one third of the country's natural gas, according to oil industry estimates, is being properly processed. A reported 10 billion cubic feet a day of untreated gas provides a vast reservoir of now valuable petroleum products waiting to be tapped.

The adsorption unit in Louisiana was set up by a group formed by Cities Service, Atlantic Refining, Tidewater Oil and Continental Oil.

GLASS REINFORCED POLYESTER wrapped around a corroded galvanized ductwork eliminated the need to tear down and replace the old duct system. In effect, the old duct served as the mandrel on which a new pipe was formed by the polyester resin mat.

Reinforced Polyester Coats and Replaces Corroded Duct Pipe

When corrosion attacked the galvanized ductwork in a plating plant and perforations had become apparent, it seemed necessary to tear down and replace the old duct system, entailing labor, replacement and plant down-time costs.

An alternate method was suggested: covering the old duct system with glass reinforced polyester. In effect, the old duct served as the mandrel on which a brand new pipe was formed.

First, the corroded ductwork was painted with polyester resin. Then a layer of glass mat saturated in the resin was placed around the duct. After another saturated mat was applied, a finishing coat of resin was brushed over the glass.

A total of 2500 feet of ductwork was covered with glass reinforced polyester in sizes varying from 6 to 18 inches in diameter.

Particles from the corroded ductwork will be removed through the ventilating system.

The polyester resin used was Atlac 382, a product of Atlas Powder Co., Wilmington, Del. The polyester coating job was done by the maintenance department of the Cleveland, Ohio, plant where the ductwork failure occurred, under supervision of Heil Process Equipment Co., Cleveland.

10-Year Performance Given On Coatings for Steels

Paint gives better protection against corrosion to nickel-copper high strength, low alloy steels than to ordinary structural steel, according to more than a decade of research by corrosion engineers with International Nickel Company, Inc.

Nickel-copper steel deteriorates more slowly than ordinary structural steel when both are exposed unpainted in marine or industrial atmospheres. When both metals are painted, paint life is longer on the nickel-copper steel.

Inco's corrosion engineers estimate that good paint can last at least 50 percent longer on low alloy steel than on ordinary structural steel.

Corrosion Meetings Scheduled in Europe Listed by Cebelcor

Among the meetings of corrosion interest scheduled to be held abroad and reported by Cebelcor in its April 1960 Corrosion Agenda are the following:

June 14-16—Annual Meeting of Dechema, Frankfurt on Main, Germany. Subjects: Organic and metallic coatings, inhibitors, physical and chemical properties of materials.

June 22-25—European Corrosion Federation, Hamburg.

August 29-September 3—Meeting of the International Committee on Thermodynamics and Electrochemical Reactions. Subjects: Diagrams tension-pH; electrochemical nomenclature and definitions; corrosion.

October 1960—32nd International Chemical Industry Convention, Barcelona, Spain. Sessions on corrosion under auspices of the European Corrosion Federation.

November 14-17—Convention and Exposition on Protection Against Corrosion, Paris. Under auspices of Society of Chemical Industry, Subjects: corrosion resistant metals and materials, corrosion inhibitors and chemical treatment of surfaces, combined methods for protecting surfaces, methods of controlling corrosion.

PVC Coatings Applied on Metal by Giant Dip Tank

A giant dip tank, said to be the world's largest tank for polyvinyl chloride dip coating of metal products, has been installed by Quelcor, Inc., of Chester, Pa. It will handle single pieces to 6½ feet in diameter and 20 feet long. Single layer coatings from 1/32 inch to ¼ inch can be applied by controlling preheat temperature of the part and time cycles.

Patent Abstract Service

Abstracts of patents can be obtained on a day-to-day service from Patent Intelligence File Company, 187 Olive St., New Haven 11, Conn. The abstracts are supplied on 7 by 10-inch loose leaf sheets with standard 3 hole-punch.

The company also furnishes an abstract service on some 300 to 400 subjects in arts, science, industry, government, etc.

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MAINTAINS TIGHT SEAL EVEN WHEN DRAG SECTION CHANGES POSITION IN CASING

This versatile and flexible "U"-Seal offers NEW ECONOMY in casing seals.

The special demonstrator pictured shows the flexibility of the "U"-Seal. The pipe position changes, but the seal remains tight. A special fungus and bacteria retardent is added to the compound for extra protection. Seals available in sizes 2" and larger.

VERSATILITY OF INSTALLATION

The fully reversible "U"-Seal is easy to install in the new "U" shape or in WmSon's familiar "Z" shape. A screwdriver is the only tool needed to tighten the two stainless steel bands.

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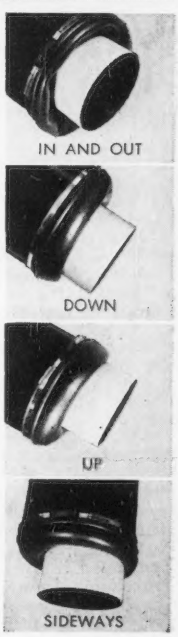


BOOK NEWS

Major Activities in the Atomic Energy Programs. January-December 1959. 628 pages, 6 x 9 inches, paper. January, 1960. Superintendent of Document, U. S. Government Printing Office, Washington 25, D. C. Per Copy, $2.

Annual report for 1959 of the United States Atomic Energy Commission.

ASTM Standards on Metallic-Coated Iron and Steel Products. Second Edition. 164 pages, 6 x 9 inches, cloth. December 1959. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, $3.50.

Consisting of 34 standards on zinc coated wire, strands, fencing, sheets, pipe and hardware all but 5 of which have been newly added, revised or have status changes.

Also included are aluminum coated wire and iron and steel articles as well as terne alloy coated sheets.

There are 25 specifications, 6 methods of test and 3 recommended practices.

Special Sources of Information on Isotopes. 54 pages, 6 x 9 inches, paper. January 1, 1960. Office of Isotopes Development, U. S. Atomic Energy Commission, Washington 25, D. C. Availability not indicated.

A collection of information on references, publications, texts, procurement, uses, services, laboratories, disposal, legislation, educational material, and other data.

Radioisotopes in Science and Industry. 176 pages, 7⅞ x 10¼ inches, paper. January, 1960. Superintendent of Documents, Government Printing Office, Washington 25, D. C. Per copy, $1.25.

A special report of the United States Atomic Energy Committee.

Although the four chapters deal with biological applications, the six concern applications of isotopes in physical chemistry. The book is a summary of information in this rapidly growing activity and brings together much data that are scattered out among numerous other sources.

Chapters significant to corrosion workers include: Physical and chemical research using isotopes, development of new applications, applications of radiation, radioisotope training, production and related programs and safety.

Appendices include data on advisory committees, radioisotope distribution data, location and type of new licensees, research and development contracts, commission films on radioisotopes and film libraries, regulations of U. S. AEC on radiation and radioisotopes, permissible weekly dosages, permissible concentrations in water above natural background, standards for protection against radiation, concentrations in water and air above natural background and others.

Electropolishing, Anodizing and Electrolytic Pickling of Metals. By N. P. Fedot'ev and S. Ya. Grilikhes. February, 1960. 285 pages, 5¼ x 8¼ inches, cloth. Robert Draper Ltd., 85 Udney Park Rd., Teddington, Middlesex, England. Per copy, $8.40.

A translation from the Russian by A. Behr.

The authors exhaustively discuss Russian practice. Revealed are details of many methods which are closely held trade secrets among Western metal finishers. Chapter headings are: Electrolytic pickling of metals, electropolishing of steel, non-ferrous light and precious metals.

Effect of electropolishing on metal properties, practical electropolishing, applications of electropolishing, anodizing aluminum and its alloys, industrial anodizing, applications of anodized aluminum and anodizing of other metals.

There is an appendix consisting of references (almost entirely Russian and Eastern European); tables of surface roughness numbers, designations of Russian aluminum alloys, and an alphabetical subject index.

Gas Shielded-Arc Welding Processes. Edited by Arthur L. Phillips. 76 pages, 6 x 9, paper. 1960. American Welding Society, 33 West 39th St., New York 18, N. Y. Per copy, $1.50.

Definitive information is given on inert-gas metal-arc, gas tungsten-arc, gas shielded-arc, welding and equipment.

Also covered are gas tungsten-arc cutting, equipment and techniques. Factors affecting cost estimation in these operations also are considered. The book is reprinted from Sections I, II and III of The Welding Handbook.

Corrosion Data Survey. 1960 Edition. Compiled by G. A. Nelson. 1960. Shell Development Co., Emeryville, Cal. Per Copy, $50.

This third edition of the Corrosion Data Survey brings up to date a collection of information on the effect of corrosives on materials of construction which probably is not equalled in any other publication of like size. The charting method developed by Shell and used in compilation of the data permits recording a large volume of information in small space. Earlier editions appeared in 1950 and 1954.

Data have been collected from corrosion literature all over the world to illustrate in a general manner the behavior of about 1500 corrosive environments in contact with about 50 structural materials. The data are posted on a series of 50,000 charts with about 50,000 reference points that list process streams ranging from abietic acid to zirconium nitrate. Concentrations range to 100 percent and temperatures from 75 to 800 F for corrosion rates less than 0.002-inch to over 0.05-inch per year.

A cross index has been provided to permit location of related compounds when a specific corrosive is not listed. Also included is a section of special tables and charts which cover among other things such data as corrosives that induce stress corrosion cracking or which induce intergranular corrosion in austenitic stainless steel. Graphical representations are given for numerous corrosion problems such as operating zones for steels in hydrogen service in which the ordinates are temperature and hydrogen partial pressure, resistance of metals to carbon monoxide with the same ordinates, with zones defined for specific lists of suitable materials. Numerous other data of similar nature are given.

Frequently throughout the charts, whenever the information is available, special editorial notes are made to specifics, such as maximum temperature limitations above the charted level; materials with special attributes, and notations concerning what might not be expected from the exposure.

Corrosion and Oxidation of Metals. By Ulick R. Evans. 1094 pages, 6 x 9 inches, cloth. May 12, 1960. St. Martin's Press, Inc., 175 Fifth Ave., New York 10, N.Y. Per Copy, $25.

A completely rewritten and revised general discussion of all aspects of corrosion and corrosion control. It is a counterpart of the same author's book, "Metallic Corrosion, Passivity and Protection," first issued in 1937 and revised in 1946. Dr. Evans, a world renowned worker in corrosion, received the 1948 Willis Rodney Whitney Award of the National Association of Corrosion Engineers in 1948 in recognition of his achievements in corrosion science.

Some idea of the magnitude of the work involved in the book may be estimated from the author index comprising about 3000 names. Dr. Evans has injected references to articles bearing on his subjects in the text, in footnotes and at chapter endings, a practice which gives his readers ample means of pursuing their interests to the fullest extent permitted by published data.

The book is organized so that the persons of diverse interests and attainments known to be interested in and concerned with corrosion control will find ample material to satisfy their demands for information. While no special effort is made to over-simplify explanations, the author recognizes that some may not have achieved competence in some of the scientific disciplines which will permit them to pursue explanations relying exclusively on mathematics, or electrochemical theory, for example. Nevertheless, these aspects of the corrosion story are neither overlooked nor slighted. The first 18 chapters have been left substantially free of equations.

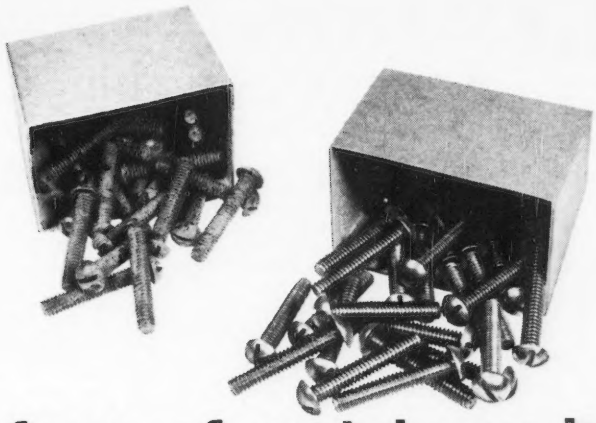
The author recognizes the fact that few can be expected to read the whole book, and surmises that many will read thoroughly those portions of pressing immediate interest and then put it aside for reference use later.

While a 16-page subject index may be somewhat abbreviated for a book of this size, the organization of the book is such that most users probably will be able to locate information without difficulty. The author's style is lucid and brief without being terse. The large number of illustrations also adds to ready understanding. Each chapter opens with a synopsis which generalizes on the material covered.

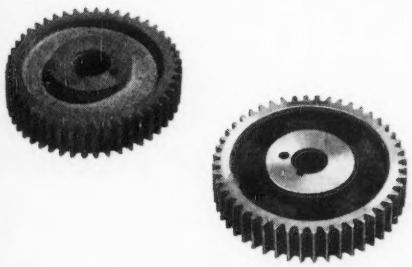
16mm Sound Color Film Made on Sandblasting

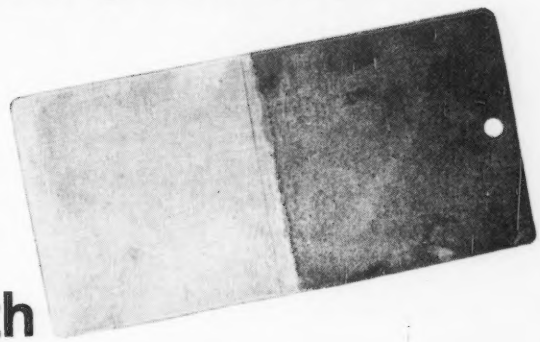
A 16mm sound color film on sandblasting has been produced by the E. W. Oakes Company. Titled "Surface Preparation Today," the 15 minute film with optical sound track shows both good and bad examples of sandblasting. It also illustrates 12 points which should be considered to obtain the most economical sandblasting operation.

The film is available to interested groups in the Southwest. Arrangements for the film can be made through Edward W. Oakes, E. W. Oakes Company, 6443 Jefferson Drive, Houston 23, Texas.



Whatever form of metal you handle...





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Your iron and steel parts in process—of every size, shape and type—will resist corrosion if you treat them with Solvay® Sodium Nitrite. Dissolved in water in economical, low concentration, it coats the corrosion-free parts pictured above—striking contrast to the untreated, corroded mates.

This easy-to-apply protection coats metal surfaces with an invisible gamma oxide film. Spray or dip it on in solution—add it to circulating water systems—combine it with phosphates for greater moisture resistance. It also reportedly suppresses degradation in aluminum, tin, monel, copper and brass.

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Please send me without cost:

☐ A. Test sample of Solvay Sodium Nitrite
☐ B. Booklet—"Sodium Nitrite for Rust and Corrosion Prevention"—SP-33A

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Ideally suited for use with anodes. Has a high carbon content and comes in sizes of 1/8-inch x 0 to 5/8 x 1/8 inch. In bulk or sacks. Prices on other sizes on request.

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Utility Line Corrosion Resistance Raised by Plumbing Code Change

Amendments to the Fort Worth, Texas, plumbing code have been adopted which are designed to improve the resistance to corrosion of gas and water lines serving utility customers in that city. These regulations recognize the necessity for the use of corrosion resistant materials underground, and especially under concrete, for the protection of steel water and gas lines and for electrical isolation of dissimilar metals connected in an aqueous environment.

The amended plumbing code provides, among other things, that:

1. Water pipes to and through buildings used to supply plumbing fixtures and water systems shall be galvanized, wrought iron or steel, extra strong lead, block tin, cast iron, tin lined tubing or Type K and L ASTM specification 99.99 percent pure copper. Water pipe installed in buildings must be copper or galvanized throughout. When dissimilar metals are used in any water system, connections between them shall be made with isolation type fittings.
2. Gas pipe and fittings underground must be either coated with coal tar enamel and wrapped with felt, or machine wrapped with plastic tape. Steel pipe with extruded plastic coatings may be used.
3. Coated pipe buried underground will be placed in a ditch free of rocks, debris from construction or extraneous material.

Practical ideas for BETTER Cathodic Protection

ARE YOU GETTING THE MOST FOR YOUR MAGNESIUM ANODE DOLLAR?

Many corrosion engineers are concerned over the composition specifications of magnesium anodes used to stop corrosion on pipe lines, oil well casing, etc.—and rightly so. But there is a more important factor that is sometimes overlooked. This is the *actual weight* of the bare anode, particularly in backfill-packaged units.

During the past several years an increasing number of the companies that use anodes have found it pays to spot check the metal weight of all anodes purchased. Often the small cost of pulling the anode from the packaged backfill has been worthwhile. 17-pound anodes have been found to weigh as little as 14 pounds, 32-pound anodes from 26 to 30 pounds, and 50-pound anodes only 44 pounds.

We at CSI feel that, regardless of the supplier, a spot check should be made of all anodes purchased. Of equal importance, requests for quotations and the subsequent purchase orders should *define all specifications.* As far back as 1945, the industry set maximum weight deviations for bare magnesium anodes at ±3 per cent of the designated weight. We suggest that, if this condition is specified and checked, you will be getting more for your magnesium anode dollar.

You'll find it to your advantage to check with CSI for engineering and installation services, and for quality supplies for both anode and rectifier installations. Estimates or competitive quotations without obligation. Let our stock-holder-employees demonstrate the economical and satisfactory service they can give you. Call or write today.

CSI

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1309 Washington Ave.
Tel. CHerry 1-7795

CORROSION SERVICES INCORPORATED
General Office: Tulsa, Okla.
Mailing Address:
Box 787, Sand Springs, Okla.
Tel. Circle 5-1351

India Holds 5-Week Refresher Course on Corrosion Prevention

A five-week refresher course on "Corrosion and Its Prevention" consisting of 60 lectures and exercises has been held in India. The course was organized and conducted by the Central Electrochemical Research Institute of the Council of Scientific and Industrial Research, Karaikudi. It was the first of its kind conducted in India.

Starting on November 9, the course terminated on December 15 with a visit to the Mandapam Field Testing Station 100 miles from Karaikudi, South India. Ten representatives from chemical and engineering industries attended.

The institute hopes to hold a similar course yearly to promote a better understanding of corrosion control principles in India. A syllabus of the course shows the following subjects covered, among others, hydrogen depolarization, high temperature oxidation, oxygen depolarization, testing, bimetallic corrosion, boilers, stress, cathodic protection, fatigue, fretting, cavitation, coatings, inhibitors, electrolytic cleaning, wood, rubber and elastomers, glass and ceramics, concrete, plastics, and statistical concepts.

Demonstrations included salt spray, conversion coatings, humidity tests, potential-time measurements, metal displacement, passivity, metal ion concentration cells, electroplating, pickling, cathodic cleaning and others.

Manganese Deposits

Rich submarine manganese deposits off Central America's western coast are to be photographed to determine their northern boundary. The U. S. Navy Electronics Laboratory, San Diego, Cal., will use a deep sea camera to photograph the area which a Russian oceanographic ship reported to be 80 to 100 percent covered with nodules of manganese. Nodules also were high in nickel and cobalt content, according to the February issue of "Industrial Research Newsletter," published by Armour Research Foundation.

Figuring tubing materials on a cost per year basis?

NEW 4-D WROUGHT IRON costs less, lasts longer

The lower the cost per year, the more economical the investment. Especially so when the material lasts a long, long time. Take the cost comparisons below. Based on actual installations, users of wrought iron cold drawn tubing have been investing wisely for many years. Now, with new 4-D Wrought Iron available, your savings are even greater.

Note: New 4-D Wrought Iron was achieved by substantially increasing the deoxidation of the base metal, slightly increasing the phosphorous content and using a more siliceous iron silicate.

Result is *increased* corrosion-resistance, *improved* mechanical and physical properties.

INSTALLATION	COST PER FOOT PER YEAR	
	WROUGHT IRON	STEEL
Hotel, Brooklyn, New York Hot ammonia gas passing through interior of tubes, cooled by salt water circulating along outside of tubes.	$ .03 (19 years)	$ .24 (2 years)
Ice Company, Chicago, Illinois Carbon dioxide condenser service.	.03 (18 years)	.05 (10 years)
Film Corporation, Binghamton, New York Tubes used in cooling service.	.04 (15 years)	.06 (8 years)
Industrial Plant, New Bedford, Massachusetts Ammonia condenser with salt water in coolant.	.04 (12-14 years)	.48 (1 year)
Industrial Plant, Toronto, Canada Tube and shell type condenser used for cooling brine with ammonia.	.01 (50 years)	.07 (7 years)
Ice Company, Aiken, South Carolina Ammonia condensers with mild brine solution containing 76 ppm sodium chloride for cooling.	.03 (18 years)	.29 (2 years)
Ice Company, Rocky Mount, North Carolina Condensers with mild brine solution containing 75 ppm sodium chloride for cooling.	.07 (8 years)	.16 (3 years)
Industrial Plant, Wisconsin Vaporizers for production of butane and propane gas. Severe stresses created by wide temperature variances.	.28 (2 years)	.96 (6 months)
Oil Company, Long Island City, New York Cool, weak ammonia liquor cools hot, concentrated ammonia liquor coming from generator on the way to absorber.	.03 (20 years)	.07 (6-8 years)
Process Company, Detroit, Michigan Heat exchangers with ammoniated brine concentration of about 10% ammonia and salt almost to saturation point.	.08 (8 years)	.16 (3 years)
Gas Company, Brooklyn, New York Ammonia condenser with cooling medium of creek water contaminated by the refuse from several nearby industrial plants.	.05 (16 years)	.22 (3-5 years)
Alkali Company, Saltville, Virginia Heat exchanger carrying ammonia liquor that is subsequently cooled by surrounding water.	.05 (16 years)	.30 (6 mos.-3 years)
Industrial Plant, Chicago, Illinois Condenser tubes in absorption system. Ammonia inside the tubing is about 200°F. and water outside the tubes is about 40°F.	.09 (9-11 years)	.28 (3 years)
Electric Utility Company, Hunts Point, New York Gas cooler drawing water from East River in New York City.	.15 (8-9 years)	.45 (2-3 years)
Warehouse & Cold Storage Corp., Springfield, Massachusetts Ammonia condensers and direct expansion cooling coil.	.02 (30 years)	.04 (12 years)

"Cost per foot per year" figures are calculated from current prices of cold drawn seamless steel tubing (ASTM A-179) and cold drawn wrought iron tubing (ASTM A-382). Because of the many variables involved, costs for installation labor, maintenance and replacement are not included. If they were, wrought iron's low cost story would, of course, be even more impressive.

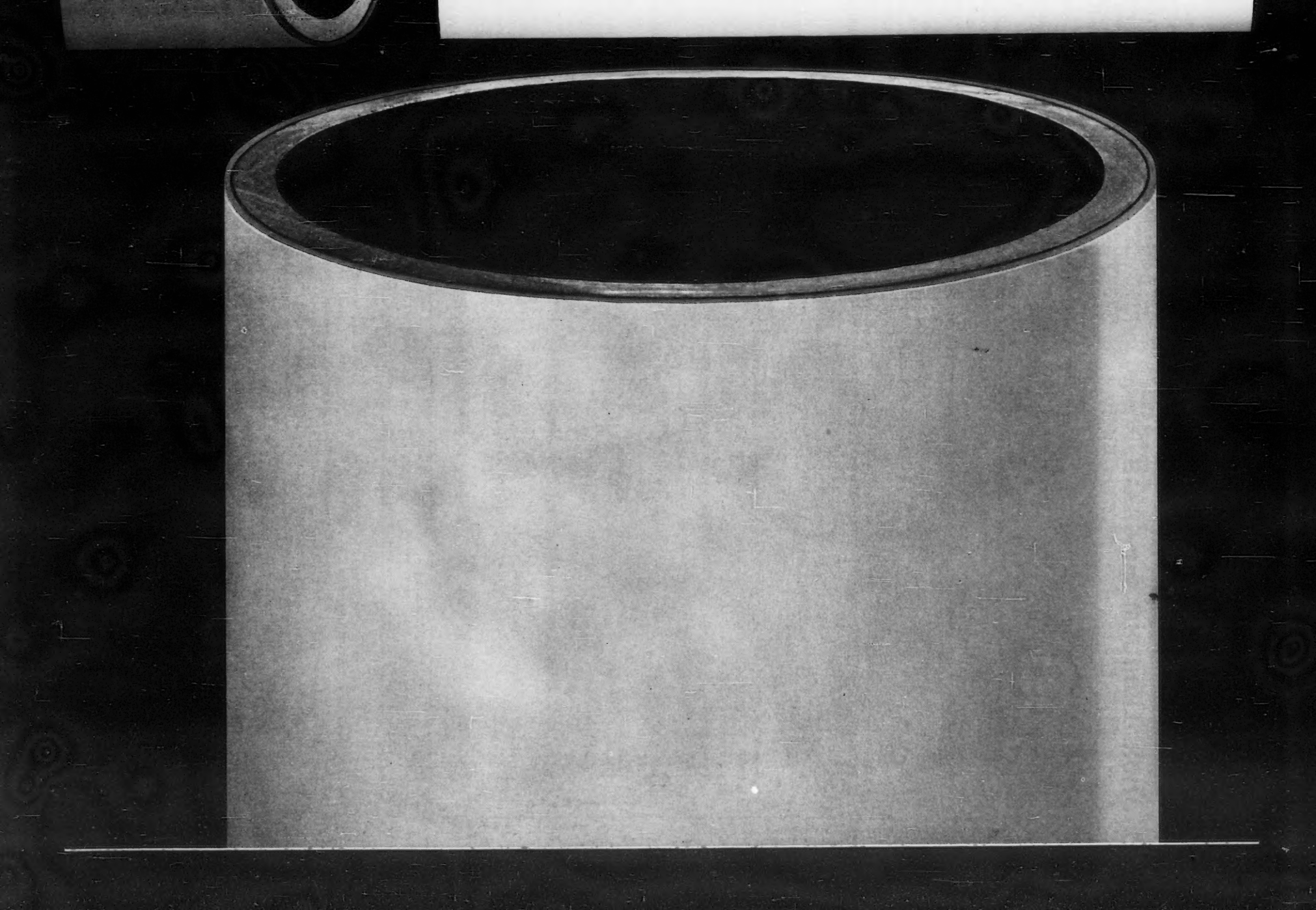
Details on any of the above installations furnished on request. Write for Wrought Iron Heat Exchanger and Condenser Tubing bulletin.

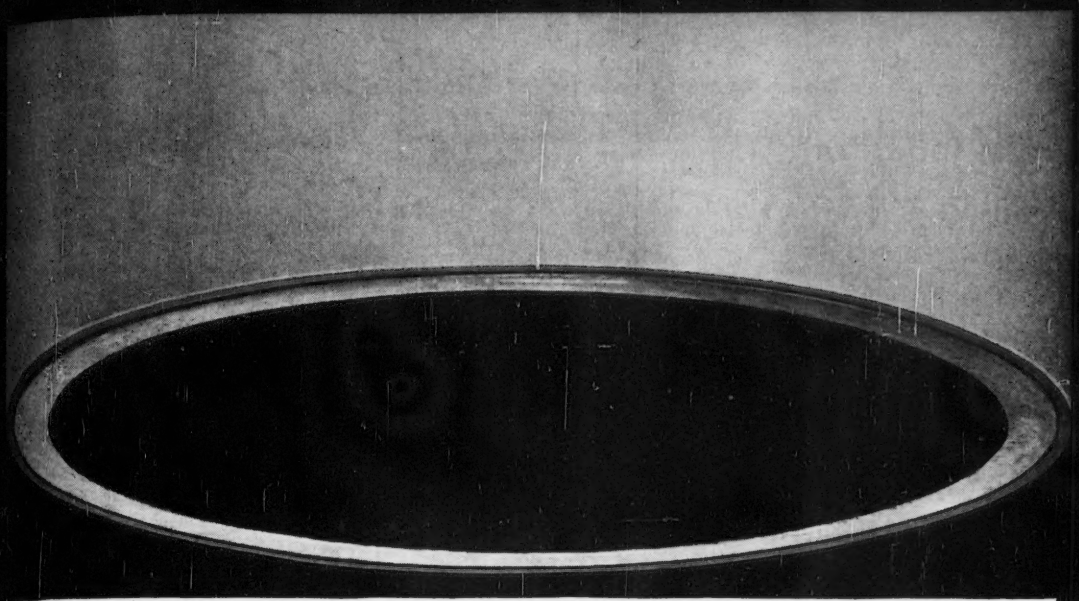
BYERS 4-D WROUGHT IRON

TUBULAR AND FLAT ROLLED PRODUCTS

A. M. BYERS CO., CLARK BLDG., PITTSBURGH 22, PA.

Corrosion costs you more than Wrought Iron





6" AND 8" X-TRU-COAT IS HERE!

PROVEN CORROSION-PROTECTION for more and bigger piping jobs comes with Republic's announcement of new 6⅝" and 8⅝" O.D. X-TRU-COAT. The new sizes bring the size range from 1.050" through 8.625" O.D. (Already our customers are suggesting that we think about producing even larger sizes. And the customer is always right.)

The ability of Republic X-TRU-COAT to stop chemical and electrolytic corrosion has been proved in hundreds of installations. The same installations have demonstrated that X-TRU-COAT's rugged plastic coating is resistant to shipping, stringing, and backfilling damage.

X-TRU-COAT's high-density polyethylene plastic is continuously extruded over "live," pressure-sensitive undercoating. This undercoat never becomes hard or brittle. It eliminates the threat of underfilm migration.

Republic also offers new X-TRU-TAPE Polyethylene Joint Wrap (in 1-, 2-, and 4-inch widths) and X-TRU-PRIMER. Both assure maximum and homogeneous joint protection for the entire pipeline. For information or quotations on the complete X-TRU-COAT package, call your nearest Republic representative or mail the coupon on the following page.

Republic X-TRU-COAT is produced under the Dekoron Process.

REPUBLIC STEEL

REPUBLIC STEEL

General Offices • Cleveland 1, Ohio

World's Widest Range of Standard Steels and Steel Products

European Inhibitor Symposium Set For September 29-30

An European Symposium on Corrosion Inhibitors will be held September 29-30 at the Sala Rossa of the University of Ferrara, Italy. A discussion session will be held on the morning of December 1.

The symposium is sponsored by the Corrosion Study Center of the Chemistry Department of the University of Ferrara, the tenth event scheduled by the European Federation of Corrosion. The National Research Council of Italy and the Italian Society of Metallurgy are patrons.

Aim of the symposium is to improve knowledge of corrosion inhibitors. Official languages will be French, English and German and simultaneous translations will be available through a translation center.

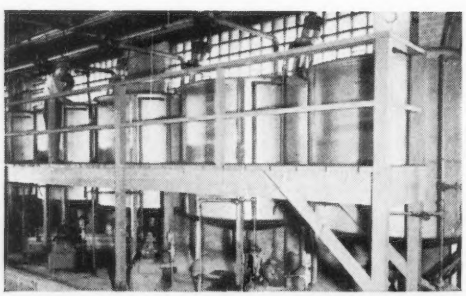
Persons planning to attend can make reservations through the Secretary, Prof. Liliana Felloni, Instituto Chimica Universita, via Scandiana 25, Ferrara, Italy, before 1 July 1960. The registration fee is Lira st 2.6.0.

•

An annual F. S. Kipping Award in Organosilicon Chemistry has been established by the American Chemical Society.

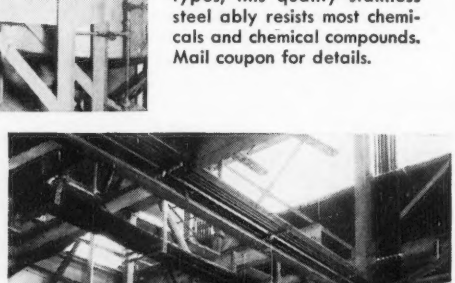
Investigate these Republic products on the basis of

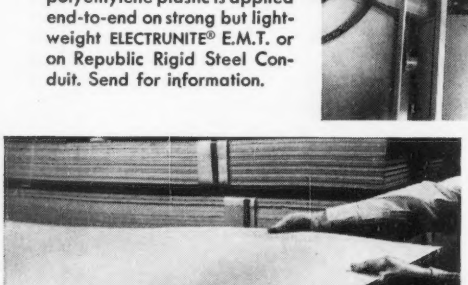
CORROSION RESISTANCE



ENDURO® STAINLESS STEEL provides vital protection against stock loss due to contamination. Available from Republic in more than 40 types, this quality stainless steel ably resists most chemicals and chemical compounds. Mail coupon for details.

PLASTIC-COATED E.M.T.— Republic's "Dekoron®-Coated" E.M.T.—outlasts standard conduit by up to ten to one in corrosive atmospheres. Tough polyethylene plastic is applied end-to-end on strong but lightweight ELECTRUNITE® E.M.T. or on Republic Rigid Steel Conduit. Send for information.





CONTINUOUS GALVANIZED SHEETS produced by Republic are known for easier fabrication. Galvanized coating is exceptionally uniform and tight—won't crack, flake, or peel under any forming operation permitted by the base metal itself.

REPUBLIC STEEL

REPUBLIC STEEL CORPORATION
DEPT. CC-9478
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Please send more information on:

☐ X-TRU-COAT
☐ Stainless Steel
☐ "Dekoron-Coated" E.M.T.
☐ Galvanized Sheets

Name_____ Title_____

Company_____

Address_____

City_____ Zone____ State_____

Library Associations Loan Classification Systems

The Special Libraries Association and the American Library Association are cooperating in a continuing project to develop and expand a loan collection of library classification schemes. This collection covers all fields of science, law, medicine, technology, social sciences and humanities.

New libraries or libraries with special collections request classifications; therefore, the collection must be kept up-to-date through addition of new schemes or with modernized versions of existing classification schedules.

Any suggested classification schemes should be sent to Jesse H. Shera, curator, SLA Loan Collection, School of Library Science, Western Reserve University, Cleveland 6, Ohio.

Cost Engineers to Meet June 13-15 in Houston

"Control and Reduction of Maintenance Costs," a paper by R. I. Reul of Food Machinery & Chemical Corp., will be presented at the technical program scheduled for the annual meeting of AACE (American Association of Cost Engineers) to be held June 13-15 at the Rice Hotel, Houston, Texas.

Other papers will deal with preliminary estimating of chemical plant equipment, important trends in depreciation and other topics.

Sixth Prestressed Concrete Institute Meeting Is Set

The 6th Annual Convention of the Prestressed Concrete Institute is scheduled for September 27-30 at the Statler-Hilton Hotel in New York City. Theme will be "Prestressed Concrete, Key to Creative Architecture and Imaginative Engineering." More information can be obtained from Norman Scott, Executive Secretary, Prestressed Concrete Institute, 205 West Wacker Drive, Chicago 6, Ill.

Ceramics Plant to Be Built

A new technical ceramics plant is to be built at Laurens, S. C., by American Lava Corporation of Chattanooga, Tenn., a subsidiary of Minnesota Mining & Manufacturing Co., St. Paul, Minn.

American Lava manufacturers technical ceramics including electrical and thermal insulators for electric, electronic chemical and other industries and ceramics that are wear and corrosion resistant for textile and wire production.

Crystal Growth Research

How layer growth in crystallization is related to other regular patterns that occur in nature and whose structures follows definite rules is described and illustrated in an article in "Research Comments," published by Evans Research and Development Corp., 250 East 43rd St., New York 17, N. Y. Confirmation of this new concept can lead to a quantitative prediction of crystal growth.

Packaging Handbook to Be Written by NACE Member

A major contract for the writing of a packaging handbook has been awarded Reed Research, Inc., Washington, D. C. The new handbook is to re-examine packaging processes, yield new package designs for modern electronic equipment and compile all known packaging information, putting specific design data at the designer's fingertips.

Gordon S. Mustin, an NACE member who has contributed work in military packaging on corrosion control and shock vibration theory and practice, will be handbook project engineer for Reed Research.

Millions of dollars are wasted each year when sensitive electronic instruments shipped by the military arrive at their destinations damaged and useless. The handbook project has been established to eliminate this problem.

ASTM to Hold 63rd Annual Meeting June 26 to July 1

Several technical papers of probable interest to corrosion engineers will be included in the 63rd Annual Meeting of ASTM to be held June 26 to July 1 at Chalfonte-Haddon Hall, Atlantic City, N.J.

These papers are "Brittle Fracture and the Strength of Metals" by E. T. Wessel of Westinghouse Electric Corp., "Role of Refractory Metals in Superalloys" by E. R. Parker of the University of California, "Additional Studies of Effect of Anodic Coatings on Fatigue Strength of Aluminum Alloys" by G. W. Stickley of Alcoa Research Laboratories, "Analysis of Determinant Factors in Radiation Effects Testing of High Polymers" by E. G. Fritz of Convair and "Long Time Atmospheric Corrosion Tests of Low Alloy Steels" by H. R. Copson of International Nickel Co., Inc.

New Instruments Transmit Written Message by Wire

Instruments which transmit written messages or sketches to any point regardless of distance over telephone or radio circuits have been developed.

The transmitting party merely writes with a ball point pen on plain or form paper. As the pen is moved, the remote receiver or receivers instantly reproduce the copy exactly as it has been written.

These Electrowriter systems can be used within plants or offices, permitting message service only or alternate written messages and voice service. For longer distances, the instruments can operate over any leased voice circuit with or without alternate telephone service.

Additional information can be obtained by writing Comptometer Corp., Communications and Electronics Division, 5600 Jarvis Ave., Chicago 48, Ill.

Next Nuclear Congress

The National Nuclear Congress is being planned for the first week in June, 1962, and will be held in New York City. Technical sessions and industrial exhibits will be included in the program. The First Congress was held in Cleveland in 1955.

Deadline Set for Replacement of Damaged Copies

A disclaimer of responsibility to replace lost or damaged copies of CORROSION has been invoked on instructions of the NACE board of directors. It has been NACE's policy to replace lost or damaged copies at no charge without any limit on the length of time between publication date of the issue and claim for replacement. Hencforth, and effective on June 1, 1960, NACE will replace without cost copies of CORROSION lost or damaged in the mails only if the claim reaches Central Office within 60 days after the date of issuance. With respect to the June, 1960 issue, for example, a claim would have to reach publication offices not later than August 5 to be honored.

New Fluorescent Lights Have Greater Brightness

A compact lighting system with a brightness level estimated to be over 300 percent greater than present fluorescent units has been developed by Sylvania Electric Products, Inc., 730 Third Ave., New York 17, N. Y.

The system combines a new aperture lamp and an optically controlled fixture. Called the Sylvania Controlled Powerbeam System, the new unit throws a narrow band of light for some distance with a minimum amount of glare, according to Sylvania.

One possible application of the new unit is a linear fluorescent automobile headlight. Light can be distributed uniformly immediately in front of and to the sides of the car with vertical cut-off.

Other applications under study include a lighting system for highways. Mounted on three foot standards, the new units have been designed to reduce glare to a minimum and give uniform distribution of light over the highway surface.

Wider Steel Sheets To Be Available From New Rolling Mill

A new rolling mill to produce steel plates wider than those previously available is under construction at U. S. Steel's plant in Gary, Ind. The mill will have a unique feature of being able to roll plates in 160 or 210 inch widths. This installation is said to be the world's first such installation.

Availability of wider steel plates will make possible greater design flexibility, thus reducing fabricating costs and improving end products made principally from steel in plate form.

The new mill also will help satisfy the increasing demand for heavy plates. Single plates weighing as much as 60,000 pounds will be rolled at the new mill, planned for completion in 1962.

Wide plates are being used for construction of such national defense items as surface ships, submarines, atomic energy installations and missiles. Other uses will include pipelines, highway bridges, refinery equipment, tanks, boilers, pressure facilities and various heavy machinery and construction applications.

The mill will be capable of rolling all grades of U. S. Steel's plate product line including carbon steels, high strength steels, alloys and stainless grades.

Symposium on Temperature Is Scheduled Next March

A national symposium on "Temperature—Its Measurement and Control in Science and Industry" will be held March 27-31, 1961, in Columbus, Ohio. It will be jointly sponsored by the American Institute of Physics, the National Bureau of Standards and the Instrument Society of America with other societies and governmental agencies cooperating.

Persons interested in contributing to the program should contact C. M. Herzfeld at the National Bureau of Standards, Washington 25, D.C.

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HOUSTON 36, TEXAS

Equipment Services NEW PRODUCTS Materials Literature

Aluminum

Important cost savings have been achieved by use of cast aluminum bus bars to feed a 7500-ampere anodizing tank, according to an electrical contractor. Connections to rectifier and tank were made by silver plating the bus bar ends and bolting the joints. The lightweight bus was cast by Kaiser Aluminum & Chemical Corp., 1924 Broadway, Oakland 12, Cal.

•

Aluminum parts for high temperature service are possible by an aluminum powder metallurgy impact extrusion process, according to Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa. Called Alcoa APM Impacts, parts made by the new process can be designed for high temperature service in such applications as atomic energy, aircraft and missiles.

Coatings, Application Equipment

High speed production of internally cleaned and coated pipe in sizes from 16 to 36 inches in diameter is one of the design features of the Crose-Perrault internal cleaning and coating machine. Pipe is cleaned with a circular brush driven at 2500 rpm. A powered car propels the brush head through the pipe. A second cleaning is achieved as the head is retracted. A spray head applies the desired coating to the pipe interior as the head is retracted for the second cleaning step. A vacuum suction line removes dust and scale from the cleaning head so that the coating can be applied on the same run of the head.

•

A spray gun for spraying plural component materials such as catalyst resins and plastics has been designed by Binks Manufacturing Co., 3114 Carroll Ave., Chicago 12, Ill. Called the Binks Turbulator and Formulator, the gun mixes catalyst, activator and resin inside the spray gun, then sprays the mixture immediately. Tests have shown that materials with reaction times as low as four seconds can be sprayed on a continuous basis with this gun, according to the manufacturer.

Glass

A glass which becomes limp when broken instead of shattering into flying fragments has been proposed for windows of industrial control rooms and other structures exposed to explosion hazards. Called laminated safety glass, it is made by sandwiching a tough, resilient plastic film between two sheets of glass, the same as used in automobile windshields. This suggestion has been made by an engineer from Monsanto Chemical Co., 800 North Lindbergh Blvd., St. Louis 66, Mo.

•

Tiny pillows and balls of glass are being produced as a low cost material for filler, packing, filtering and tumbling applications. The pillows, both solid and hollow, are made in lengths to one-half inch. The balls can be made in diameters to one-half inch. The hollow pillows provide a low density filler material for such applications as packing in aircraft wings for support and buoyancy and as a filler in casting of large plastic pieces. Solid pillows are being used in chemical processing as filler in refractionating columns and in filter beds. Their tumbling action provides the necessary agitation in electroplating operations.

Instruments

Controlled measurement of pre-determined quantities for batching and processing systems where such corrosive liquids as acids and alkalies are used is provided automatically by a stainless steel Auto-Stop meter, according to the manufacturer, Neptune Meter Co., 47-25 34th St., Long Island City 1, N.Y. The new Auto-Stop meter has a capacity range from 20 gpm minimum to 100 gpm maximum. Meters can be calibrated for U. S. or Imperial gallons, liters or pounds.

•

A new improved permanent magnet alloy possessing high coercive force and energy product values has been developed by Hoskins Mfg. Co., 445 Lawton Ave., Detroit 8, Mich., for such applications as timer motors, speedometers, aircraft instruments, electronic equipment and control systems. Hoskins Cunife magnet alloy is claimed to have excellent ductility, malleability and machinability. It also can be readily stamped, machined or formed by conventional methods into a variety of complex, intricately shaped parts with no finishing operations required.

•

A pipeline holiday detector which provides constant voltage in any climate has been developed by Tinker & Rasor, 417 Agostino Road, San Gabriel, Cal. Designated as Model HP, the portable detector requires no generator and uses a new electrical field device consisting of a double electrode or plastic coated saddle. This flexible pad is attached directly to the instrument carrier and creates a constant inspection voltage which is adjustable. The detector will perform equally well on wet or dry coatings, according to Tinker & Rasor.

•

A self-contained electric alarm system that gives audible and visible warning of unsafe temperature conditions is available from Mack Electric Devices, Inc., Wyncote, Pa. Designed for applications such as freezers, blood banks, sterilizers, laboratories, vaults, etc., where temperature maintenance is critical, the alarm has auxiliary battery power.

•

A combined pH meter and strip chart recorder is available from Analytical Measurements, Inc., 585 Main St., Chatham N.J. The instrument uses an electronically modulated amplifier that compensates for line voltage fluctuations. A strip chart recorder forms the front panel of the instrument and contains a 63-foot roll of chart paper that is designed to last for 31 days at 1 inch per hour. Other chart speeds are available to 16 inches per hour by a simple gear change. Clogged pen problems are eliminated by use of a pressure sensitive coating on the chart paper. A switch on the front panel permits disconnection of the chart drive so that the instrument can be used as an indicating pH meter.

Metals, Ferrous

A revised data book on chromium-nickel stainless steels is available from Republic Steel, 1441 Republic Bldg., Cleveland 1, Ohio. It contains general information and technical data on Republic's Enduro Stainless Steel. One section explains the corrosion resistance of stainless steels.

•

Tissue paper thin strips of stainless steel alloy, wound layer upon layer, are being used to contain the forces developed in rocket engines fueled by solid propellants. In experimental fabrication conducted by Ryan Aeronautical Co., San Diego, Cal., multiple strips of ultra-high tensile alloy were wound and spotwelded into a strong cylindrical rocket chamber that withstands 305,000 psi hoop stress. The stainless steel used was AM-355, developed by Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.

Metals, Non-Ferrous

Metal working facilities for manufacture and processing of magnesium and aluminum are described in a brochure available from Dow Metal Products Co., Division of Dow Chemical Co., Midland, Mich. The brochure includes information on rolled and extruded products, sand and permanent mold castings, die castings and fabricated assemblies.

Non-Metallics

An up-to-date summary of the forms, properties and applications of silicones products available from Dow Corning Corp., Midland, Mich., is published in a brochure which includes tables, graphs and other data as an engineering guide.

•

Development of inorganic polymers with good properties at high temperatures is included in an Air Force research contract awarded to Monsanto Chemical Co., 800 North Lindbergh Blvd., St. Louis 66, Mo. The Air Force hopes that a polymer can be developed to withstand high temperatures resulting from aerodynamic heating in high speed flight and from rocket engine exhausts. Available materials such as rubbers, lubricants and rigid plastics do not withstand the heat generated.

Pipes

Higher yield strengths and higher temperature range are characteristics of a new condenser tube, Hi-Yield 70/30 Cupro Nickel, available from Bridgeport Brass Co., Bridgeport 2, Conn. Yield strengths are more than twice standard 70/30 Cupro Nickel, and the useful range of the alloy is extended to 750 F, according to the producer.

•

Industrial fire hose jacketed with Dacron

polyester fiber for abrasive and chemical resistance is described in technical bulletin D-115 available from Du Pont Company, Wilmington 98, Del. Chemical exposure tests are given in tabular form, showing acid concentration, temperature, time and their effect on hose strength.

Plastics

A polyolefin plant designed for an initial annual production of 40 million pounds of polypropylene has been opened by Humble Oil & Refining Company at its Baytown refinery in Texas. Polypropylene is strong, resilient, rigid, light weight and resistant to heat and chemicals. This petroleum based plastic is extruded in spaghetti fashion, chopped into small pellets and packaged in bags for shipment to product manufacturers.

•

Tetrafluoroethylene piping for continuous service with hydrofluoric and other acids at temperatures to 500 F has been introduced by Resistoflex Corporation, Roseland, N.J. Called Fluoroflex-TS dip pipes, they are designed to withstand severe agitation and thermal shock, including the packing gland and flanges. Type TS dip pipes are especially suitable for use in reaction vessels and will not contaminate or affect the reaction materials, according to the manufacturer.

•

Molded nylon parts available from stock molds are illustrated in a new catalog available from Nylomatic Corp., 122 W. Trenton Ave., Morrisville, Pa. Among the assortment of parts are bushings, washers, rollers, gears, bearings, glides etc.

Research

Scott Paper Company has awarded a general contract for construction of its new Research Center in Delaware Country, adjacent to the Philadelphia International Airport.

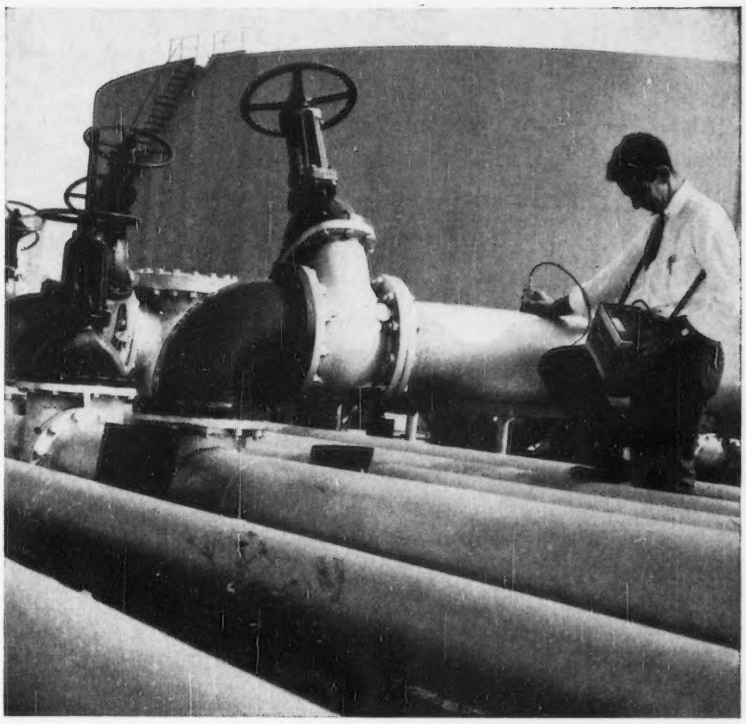
•

Site for future research facilities for General Telephone & Electronics Laboratories, Inc., has been acquired near Pal Alto, Cal. This new subsidiary of General Telephone & Electronics Corporation was formed recently to handle basic research and advanced development for the parent company.

Color Slide-Talk on 1960 Corrosion Show

A 35-mm color slide show of about 100 slides of exhibits at the 1960 Corrosion Show at Dallas has been prepared and is available for showing at NACE Section meetings. The show, which has a commentary on specific items exhibited, is available on a first-come, first-served basis on application to G. A. Rolak, NACE Central Office.

The show provides an opportunity for NACE members who were unable to visit the Corrosion Show personally to see some of the equipment on display. While the presentation does not include all the exhibits, it will give a good idea of the show. Presentation time should vary between an hour and an hour and a half.



The Sperry ultrasonic thickness gage, portable, self-powered and direct reading is ideal for field use.

Corrosion measurements IN SECONDS!

Get fast, accurate ultrasonic measurement of wall thickness with Sperry's new UT gage. Battery operated and completely transistorized, the UT weighs only 10 lbs. — size 7½" x 5½" x 11". Unlike resonance thickness gages, the UT gage uses the pulse echo method and so makes possible thickness measurements where surfaces are off parallel, or when they are pitted or rough. Measurements are read directly on a calibrated meter — accurate within 1% of full scale and will measure steel thickness from .07 to 1.5 inches. Alarm lamps are provided for use in dark areas, or for go-no-go operation.

For more information on this and other ultrasonic, X-ray or magnetic particle equipment, write to Sperry, pioneer in nondestructive testing.

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2706 Shelter Rock Road, Danbury, Connecticut

MEN in the NEWS

DeWayne Higdon, an NACE member, is the South Texas regional sales manager for Tubular Lining Corp., Houston, Texas.

•

NACE member **Bernard M. Saffian** has joined the Chamberlain Laboratories of U. S. Stoneware Co., Stow, Ohio, as associate director.

•

Maynard H. Jackson, an NACE member, is president of the newly organized M. H. Jackson Pipeline Supply Company, 1017 Gulf Bldg., Tulsa, Okla. **R. B. Wallace** will be in charge of product sales; **Woodrow Cole** will be treasurer and office manager.

•

G. H. LeFevre, an NACE member of U. S. Smelting Refining and Mining Co., New York City, has been re-elected as treasurer of the American Zinc Institute.

NACE Member **Alan G. Caterson** has been appointed technical editor of Crucible Steel Company's newly created Information Services Department.

•

Joseph E. Rench, member of NACE's board of directors, who is vice president of Napko Corp., Houston, Texas, has been assigned responsibility for the sales program of the company.

•

NACE Member **Robert D. Jackson,** formerly associated with Liberty Engineering Mfg. Co., Louisville, Ky., has opened his new firm, Plastics Engineering of Hawaii at 116 South King St., Honolulu 13, Hawaii, which will offer consulting and application services on plastics for corrosion control.

•

E. M. Adams of Dow Chemical Co., Midland, Mich., has been elected chairman of the Manufacturing Chemists' Association's Air Pollution Abatement Committee.

•

Wright Chemical Corporation has announced the appointments of **Paul G. Bird, John J. Kaneski, Jr.,** and **Robert O. Lewis** to the Water Treating Division Executive Committee.

•

Harry A. Bright, chief of the Analytical Chemistry Section of the National Bureau of Standards, retired recently after 47 years of service.

•

M. L. Clough is the northeast regional manager for Ebasco Service Incorporated. His headquarters will be the company's offices at 2 Rector St., New York 6, N.Y.

•

R. C. Crowe has been named product sales manager of the Wolverine Tube Division of Calumet & Hecla, Inc., 17200 Southfield Rd., Allen Park, Mich.

•

Kenneth A. DeLonge has been appointed manager of direct sales in the Primary Nickel Department of International Nickel Co., Inc., 67 Wall St., New York 5, N.Y.

•

Carmen A. Esposito has been named a product specialist for heat exchangers by Corning Glass Works, Corning, N.Y.

•

Louis Fernandez has been appointed director of sales for marketing administration of Monsanto Chemical Company's Inorganic Chemicals Division, 800 North Lindbergh Blvd., St. Louis 66, Mo.

•

James F. Garland has been appointed a corrosion engineer with A. M. Byers Company, Pittsburgh, Pa.

•

Robert E. Hilleman has been appointed territorial manager assigned to Carpenter Steel Company's Alloy Tube Division at 3942 Laclede Ave., St. Louis, Mo.

•

Richard L. Hoff has been appointed development metallurgist by Superior Tube Co., Norristown, Pa.

•

NACE Member **James C. Holzwarth** has been promoted to assistant head of the Metallurgical Engineering Department at General Motors Research Laboratories, GM Technical Center, Warren, Mich.

•

Bernard Kearney, president of Torsion Balance Co., Clifton, N.J., has been elected president of the New York and New Jersey Branch of National Metal Trades Association.

•

Charles L. Kerr, president of Kerr-Lakeside Industries Inc., of Cleveland, Ohio, has been elected president of the National Screw Machine Products Association, 2860 East 130th St., Cleveland 20, Ohio.

•

William F. LeFevre has been appointed director of advanced product research for White Motor Co., 842 E. 79th St., Cleveland 1, Ohio.

•

H. Dale Long, president of Scully Jones and Co., Chicago, has been elected president of the American Society of Tool and Manufacturing Engineers, 10700 Puritan, Detroit 38, Mich.

•

John A. March, vice president of International Nickel Company, Inc., was elected president of Inco's Huntington Alloy Products Division. **Paul Queneau** has been elected technical assistant to the president of International Nickel Company of Canada, Limited.

•

Howard R. Medici has been appointed chairman and **Glenn L. Pitzer** president of Visking Company, division of Union

(Continued on Page 56)

POSITIONS WANTED AND AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point type. Advertisements to other specifications will be charged for at $10 a column inch.

Positions Available

Wanted by Centre Belge d'Etude de la Corrosion: An engineer and a PhD in chemical sciences and a technical engineer for scientific and technical studies in electrochemistry and corrosion. Good basic education and proficiency in languages indispensable. Begin immediately if possible. Write Cebelcor, 24, Rue de Chavaliers, Brussells 5, Belgium.

Chemical Engineer for corrosion inspection program. Involves process corrosion studies, materials testing, process equipment inspection, metallurgical studies and interpretation. Prepare comprehensive reports. Up to 3 years' experience in this field. Write N. B. Russell, P. O. Box 1311, Monsanto Chemical Company, Texas City, Texas.

GAS ENGINEER

Fast growing and progressive midwest natural gas utility, with over 16,000 customers is seeking an engineer with at least 3 or 4 years' gas utility operation experience since graduation to take a position in a supervisory capacity. Prefer man about 30 years of age with technical background and experience in corrosion and cathodic protection and with executive ability to supervise this type of work. Send full resume of experience, age and salary requirements. CORROSION, 60-18.

UNUSUAL OPPORTUNITY

Technical service and sales work for sanitary or petroleum engineer with experience in water flooding Salary and commission. Write fully, including recent photograph, to Buckman Laboratories, Inc. Memphis 8, Tennessee.

Manufacturers' Agents

Opportunity—Complete line of corrosion control coatings, floorings etc, offered by firm with excellent technical reputation and straight-forward sales policies. Aggressive but service minded agents wanted for several exclusive territories. CORROSION, Box 60-15.

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Experienced Sales & Service Representative. Chemical education with ten years' experience in laboratory and sales of coatings and chemicals. Desires position with reputable organization for western Pennsylvania area. Best references. CORROSION, Box 60-16.

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•

News deadline for CORROSION is the 10th of each month.

•

A Short Course on Process Industry Corrosion, sponsored by NACE Technical Committee T-5 and Ohio State University, will be held Sept. 12-16 at Columbus.

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Federated galvanic anodes, specially designed to protect pipelines and other buried structures, are just one of the wide range of Federated materials to control corrosion. Federated's Corrosion Advisory Service can recommend the best for you . . . magnesium or zinc anodes; lead sheet, pipe, and fittings; zinc and zinc alloys for galvanizing; copper and aluminum alloys; and plating materials that include nickel, copper, lead, cadmium, zinc and silver anodes, nickel salts and addition agents for plating baths. For complete data, write or call—Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y. or a nearby Federated sales office.

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IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

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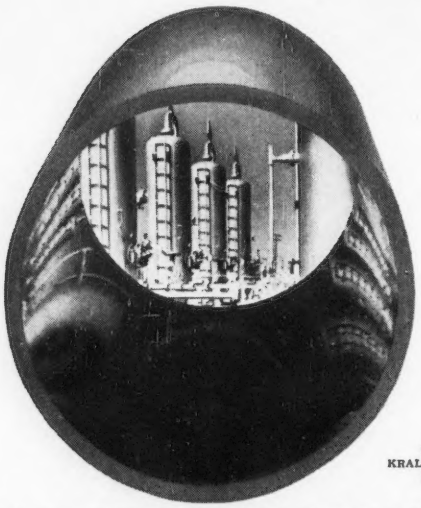

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MEN in the NEWS

(Continued From Page 54)

Carbide Corp., 30 East 42nd St., New York 17, N.Y.

•

Julius Merl has joined Water Service Laboratories, Inc., 615 West 131st St., New York 27, N.Y., as service coordinator.

•

George A. Omohundro has joined American Viscose Corporation, 1617 Pennsylvania Blvd., Philadelphia 3, Pa., as chemical process engineer supervisor in the company's Central Engineering Department at Marcus Hook, Pa.

•

Henry F. Payne, professor in charge of organic coating research and technology at the University of Florida, Gainesville, will give the annual Joseph J. Mattiello Memorial Lecture at the 38th Annual Meeting of the Federation of Societies for Paint Technology this fall. An article on coatings by Professor Payne appears in the Technical Topics Section of this issue of CORROSION.

•

Christian H. Pedersen has been appointed director of the mechanical development department at Superior Tube Company, Norristown, Pa.

•

Douglas L. Peterson has been appointed technical sales representative in the north central region for Union Carbide Plastics Co., 10421 W. 7 Mile Road, Detroit 21, Mich.

•

A. C. Polk was named president of Dowell of Canada, Ltd., Calgary, Canada.

•

Clifford Pountney, Jr., has been appointed research director for the DeVilbiss Company, Toledo 1, Ohio.

•

Robert E. Savage has been appointed Foundry Industry Manager for the Primary Nickel Department of International Nickel Co., Inc.

•

Lawrence J. Smith has been appointed vice president in charge of research at Bell & Gossett Company, Norton Grove, Ill.

•

Ross E. Smith, Jr., has been appointed electrical products sales representative for the new sales office of Republic Steel Corporation's Steel and Tubes Division at Charlotte, N.C.

•

C. E. Upson, general superintendent of communications for Natural Gas Pipe Line Company of America, Chicago, was elected president of the Petroleum Industry Electrical Association.

•

NACE Member **James S. Vanick,** research metallurgist with the Development and Research Division of International Nickel Co., Inc., has retired after 38 years of service.

•

Harry B. Warner has become president of the B. F. Goodrich Chemical Company.

•

W. E. Weber, an NACE member, has been appointed manager of the Pacific Coast Division for A. M. Byers Company, Pittsburgh, Pa. His headquarters will be the Russ Building, San Francisco, Cal.

Reorganization Completed For Committee T-1

Eight New Units Are Formed to Overcome Duplicated Effort

The proposed reorganization of Technical Group Committee T-1 (Corrosion in Oil and Gas Well Equipment) was approved at the Dallas Conference. This reorganization was considered necessary to overcome repetition and duplication of meetings and committee effort.

Eight unit committees were formed in the T-1 reorganization. Scopes of these units and officers elected for four of them are given below.

Chairman of T-1 is W. C. Koger of Cities Service Oil Co., Bartlesville, Okla. Vice chairman is J. A. Caldwell of Humble Oil & Refining Co., Houston, Texas.

Committee T-1 is concerned with the broad subject of oil and gas well equipment corrosion. The committee proposes to gather and compile data on the environmental cause of this corrosion and on methods of controlling this problem. Where possible, the committee also is attempting to promote correlated cooperative tests of materials in connection with the various problems.

T-1A

Unit Committee T-1A (Corrosion in Oil and Gas Well Equipment, Los Angeles Area) restricts its activities to the Los Angeles petroleum producing area and keeps the parent committee advised of developments in the applications of new techniques introduced in that area.

R. L. Davis of Superior Oil Co., South Pasadena, Cal., has been elected chairman of T-1A.

T-1B

The producing area of Calgary, Canada, is the geographic scope of Unit Committee T-1B (Corrosion in Oil and Gas Well Equipment, Calgary, Area). It also will advise T-1 of new developments and techniques.

Barrett

Battle

Caldwell

Fincher

Koger

Landers

McGlasson

Nathan

Prange

Roberson

Robinson

Simmons

T-1C

Unit Committee T-1C (Detection of Corrosion in Oil Field Equipment) is interested in evaluation of methods and tools used to determine whether corrosion is occurring and the amount and location of such corrosion.

Officers recently elected for T1-C are Chairman J. P. Barrett of Pan American Petroleum Corp., Tulsa, Okla., and Vice Chairman F. A. Prange of Phillips Petroleum Co., Bartlesville, Okla.

T-1D

Development, evaluation and standardization of laboratory testing procedures to screen and evaluate corrosion inhibitors is the proposed scope of Unit Committee T-1D (Control of Oil Field Corrosion by Chemical Treatment). It also will be interested in field evaluation of corrosion inhibitors and evaluation of inhibitor application methods.

Officers for T-1D are Chairman C. C. Nathan of Texaco, Inc., Bellaire, Texas, and Vice Chairman John R. Bruce of Shell Oil Co., Denver, Colo.

T-1E

Unit Committee T-1E (Cathodic Protection of Oil Field Equipment) will be concerned with application and evaluation of cathodic protection of all types of oil field equipment, both surface and sub-surface installations.

T-1E officers are Jack L. Battle of Humble Oil and Refining Co., Houston, Texas, and Vice Chairman J. E. Landers of Continental Oil Co., Ponca City, Okla.

T-1F

Evaluation of metals for use in oil field environments and development of metal selection principles will be the interest areas of Unit Committee T-1F (Metallurgy of Oil Field Equipment).

T-1F officers are Chairman R. L. McGlasson of Continental Oil Co., Ponca City, Okla., and Vice Chairman T. M. Krebs of Babcock & Wilcox Co., Beaver Falls, Pa.

T-1G

Unit Committee T-1G (Protective Coatings and Non-Metallic Materials for Oil Field Use) is interested in testing, applying and evaluating protective coatings and non-metallic materials for the oil and gas producing industry.

Recently elected officers for T-1G are Chairman D. R. Fincher of Tidewater Oil Co., Houston, Texas, and Vice Chairman G. R. Roberson of Standard Oil Company of Texas, Houston.

T-1H

Collecting corrosion cost data and evaluating the effectiveness of corrosion control programs for all phases of the industry will be included in the scope of Unit Committee T-1H (Economics of Corrosion Control).

T-1H officers are Chairman R. M. Robinson of Continental Oil Co., New Orleans, La., and Vice Chairman E. J. Simmons of Sun Oil Co., Dallas, Texas.

Seventeen Committees Report on Dallas Meetings

Discussion and action on a diversity of corrosion topics were included in the meetings held by 65 technical committees during the 16th Annual NACE Conference in Dallas, March 14-18. Reports from 17 of the committees are summarized below.

T-5E

Unit Committee T-5E (Stress Corrosion Cracking of Austenitic Stainless Steel) had 24 members and guests at its meeting. Discussions covered many problem areas including methods for chloride analysis, standard type stress specimens, and case histories of cracking. Slides were presented on cathodic protection to prevent stress corrosion cracking on Type 304 in boiling magnesium chloride. The possibility of anodic protection was discussed briefly.

The committee was informed that the joint T-5E and ASTM-D-10 report on stress corrosion cracking is to be issued in April, 1960.

T-5B

Methods of testing materials and structures for aircraft and missiles were discussed at the T-5B (High Temperature Corrosion) meeting. A guest discussed his company's methods of testing materials and structures for their ramjet engine, arc plasma and heating lamp facilities which can expose materials and complete structures to programmed heating curves to simulate actual environmental experience.

Other topics discussed included diffusion coatings used to provide high temperature protection and high temperature thermal protective systems on various Air Force weapon systems.

T-4E

Further trials of pipe in various waters to determine more quantitative data were discussed at the Dallas meeting of T-4E (Corrosion by Domestic Waters). It was agreed to (1) limit number of waters to several types, (2) limit work to galvanized wrought iron, galvanized steel and alclad aluminum pipe, (3) eliminate all effect of copper deposits in the test, (4) obtain more data on water velocity, volume, etc. At least seven cooperations were obtained and the pipe sections were to be obtained, if possible, directly from suppliers.

Cooperation of the US Public Health Service was to be sought so that test specimens be included at the departments test locations.

Following a discussion of the need for work on corrosion of domestic appliances such as washers, etc., an assignment was made to determine the interest of manufacturers in such a project.

T-4E-1

Task Group T-4E-1 (Hot Water Tank Corrosion) discussed and tentatively approved a questionnaire for distribution to gas, electric and water utilities and to government housing projects on the relative service life of various types of water heaters in different types of domestic waters.

T-4G

Unit Committee T-4G (Protection of Pipe Type Cables) discussed the following topics during its Dallas meeting: causes of corrosion of steel pipe, tests and surveys, coatings, cathodic protection, grounding and safety. A report is being prepared from replies received from the committee questionnaire on "Protection of Pipe Type Cables."

T-5A

T-5A (Corrosion in Chemical Processes) had an estimated attendance of 50 at its meeting in Dallas. Those present voted for a mid-year meeting in Huntington, W. Va., during the Northeast Region Conference, October 11-14.

No task groups were terminated, but several consolidations were made under the present set-up of T-5A-1, T-5A-2 and T-5A-3. Chairman of T-5A-1 is N. D. Groves of Carpenter Steel Co., Reading, Pa. T-5A-2 chairman is R. H. Scott of Celanese Corp., Bishop, Texas. T-5A-3 chairman is George P. Gladis of International Nickel, New York City.

T-4J

At the Dallas meeting of T-4J (Cathodic Protection of Cable Sheaths), a task group was formed to consider the effect and to collect information on use of deep well anodes on metallic sheathed cable systems. Vernon Pike was appointed chairman of the group.

T-6G

About 90 members and guests attended the Dallas meeting of Unit Committee T-6G (Surface Preparation for Organic Coatings). Discussions centered on surface preparation standards from the Steel Structures Painting Council, ASTM, NACE and Sweden. The committee will attempt to correlate these standards and specifications.

A film on surface preparation by sandblasting produced by E. W. Oakes of Houston, Texas, was shown.

Two studies on present methods for estimating blast cleaning requirements will be presented at the committee's next meeting.

T-6F

"Is it possible to predict field service life from laboratory evaluation?" This question led to a lively discussion at the Dallas meeting of Unit Committee T-6F (Protective Interior Linings, Applications and Methods).

Other business included reports from six task groups.

T-9B

A proposed change in creosote specifications received favorable comment at the meeting of T-9B (Preservatives and Their Appraisal). The assay method of determining the amount of creosote in pilings was discussed with the following conclusions drawn:

1. It is necessary that the assay method to be used to assure the desired creosote retention for marine piling.

2. Retention necessary for marine piling cannot be obtained when green piling is used unless special equipment is used. Few treaters in the southern United States have the necessary equipment for rapid seasoning of green piling. As a result, it is difficult to obtain the necessary retention.

3. Every charge should be assayed by the treater, consumer or both.

T-2k

Coating evaluation records and information were discussed at the Dallas meeting of T-2K (Prefabricated Plastic Film for Pipe Line Coating). Meetings were scheduled for the Northeast and South Central Region Conferences at Huntington, W. Va., October 11-14, and at Tulsa, Okla., October 25-28. Reports from task groups were given also.

T-2M

Reports from seven task groups were given during the Dallas meeting of T-2M (Aluminum Pipeline Corrosion). Forty members and guests attended. Data is currently being accumulated by the task groups for reports at a later date.

T-6D

About 70 members and guests attended the Dallas meeting of T-6D (Industrial Maintenance Painting). Discussions included such painting problems as specifications, economics of maintenance painting, shop cleaning and priming specifications, painter education and safe working conditions.

The committee's next regional meeting will be held during the South Central Region Conference, October 25-28, in Tulsa, Okla.

T-2

Over 40 guests and members were present at the T-2 (Pipe Line Corrosion) meeting held in Dallas. Chairman W. H. Stewart of Sun Pipe Line Co., Beaumont, Texas, led the discussion on the work of the T-2 Task Group on "Minimum Requirements." (See CORROSION, May, Page 28.) Reports also were given by each unit committee chairman.

T-4A

About 80 guests and members were present for the Dallas meeting of T-4A (Effects of Electrical Grounding on Corrosion). A. F. Minor was appointed chairman of a steering committee to set up Task Group T-4A-4 (Coordination of Utility Grounding Practices).

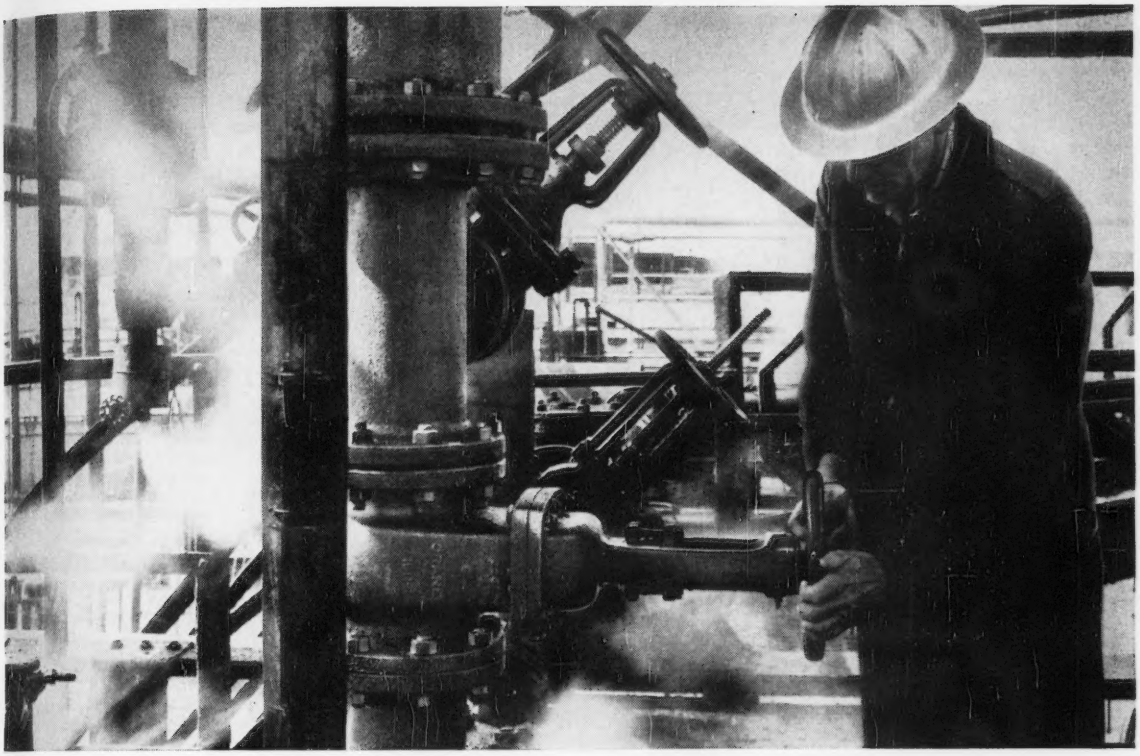
A report was given by Task Group T-4A-3 "Methods and Materials for Grounding. A lively discussion followed this report.

T-3

Reports from five unit committees were given at the Dallas meeting of Group Committee T-3 (General). The report from T-3H (Tanker Corrosion) included discussion of two serious explosions on tankers last year which may have been caused by magnesium anodes. (See Editorial on Page 7, May issue of CORROSION.)

T-4H

Unit Committee T-4H (Tests and Surveys of Cable Sheaths) had an estimated attendance of 37 at its meeting in Dallas during the Annual Conference. A member reported on work done with a zero resistance type ammeter for measuring cable sheath current. Another member reported on investigating "clip-on" type meters for measuring d-c current flowing on conductors and cable sheaths and also reported on development work done on a device for making rapid duet surveys. A discussion was held on the question of which data, current or voltage was more significant in a duct survey.



30% nickel stainless valve holds off sulfuric acid 14 months

Outlasts others by better than 2 to 1

Handling enough hot sulfuric acid sludge to ruin at least two ordinary valves, this Crane gate valve needed only minor repairs after 14 months. Other valves lasted six months . . . some only three. Here is what helped make the difference:

Stainless alloy plus design

All acid-exposed parts of the valve were cast from "Craneloy 20"*. This 30% nickel, 20% chromium alloy containing molybdenum and copper effectively resists a wide range of hot sulfuric acid concentrations. It also resists certain other mineral acids and many oxidizing and reducing media.

The design of the valve incorporates a special split-wedge disc construction. This minimizes the possibility of galling, reduces wear on seating faces while providing for tight shutoff.

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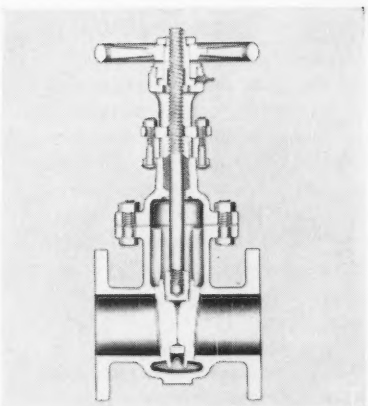
In valves, fittings, instrument parts or special equipment operating in corrosive atmospheres, stainless castings offer an excellent opportunity to hold down replacement costs and downtime. So, whether your problems involve chemical corrosion . . . or a punishing combination of corrosives, heat and shock . . . a suitable nickel-containing casting alloy probably can help.

Would you like further comprehensive information? Our new 64-page booklet "Heat- and Corrosion-Resistant Castings — Their Engineering Properties and Applications" is yours for the asking.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N.Y.



Crane Combines Corrosion-Resisting Alloy, Wear-Avoiding Design. High nickel and chromium contents of the alloy, combined with copper and molybdenum, afford outstanding resistance to sulfuric acid and other corrosives. Split-wedge disc closure enables parts to seat with lighter-than-average pressure... minimizes critical wear and galling. *Crane Co. trademark

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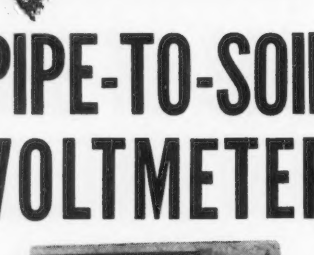

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The new Dacca Pipe-to-Soil Voltmeter incorporates features found in far more expensive types — yet it costs less than half. It accurately measures pipe-to-soil, structure-to-structure and anode-to-pipe potentials under any resistance conditions. Simple and fast, it uses only one balancing knob and is easily held in one hand. Extremely easy to understand, it is durable, reliable and compact and uses standard flashlight batteries.

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Committee Officers Recently Elected

T-4G Officers

Frank E. Kulman, senior engineer with Consolidated Edison Company of New York, Inc., New York City, has been elected chairman of Technical Unit Committee T-4G (Protection of Pipe Type Cables). R. C. Jacobsen of the Hydro-Electric Power Commission of Ontario, Toronto, Canada, was elected vice chairman.

T-2 Chairman

W. H. Stewart of Sun Pipe Line Company, Beaumont, Texas, has been reappointed chairman of Technical Group Committee T-2 on Pipe Line Corrosion to continue work on the T-2 Minimum Requirements for Buried Pipe Lines. (See article on Page 28 of the May issue of CORROSION.) The committee plans to complete the report this year.

T-4 Chairman

J. B. Prime, Jr., of Florida Power and Light Company, Miami, Fla., has been appointed chairman of Technical Group Committee T-4 on Utilities succeeding D. R. Werner, who has been chairman for the past two years.

T-6 Chairman

O. H. Fenner of Monsanto Chemical Company, St. Louis, Mo., has been appointed chairman of Technical Group Committee T-6 on Protective Coatings. He succeeds L. S. Van Delinder, T-6 chairman for the past three years.

T-8 Chairman

Cecil O. Phillips, Jr., of Humble Oil and Refining Company, Baytown, Texas, has been appointed chairman of Technical Group Committee T-8 on Refining Industry Corrosion. He succeeds E. B. Backensto, T-8 chairman for the past two years.

T-5 Vice Chairman

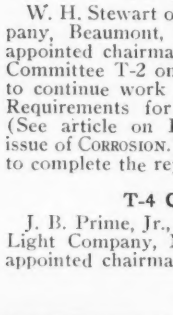
W. H. Burton, General Chemical Division of Allied Chemical Corp., Camden, N.J., has been elected vice chairman of Technical Committee T-5 on Corrosion Problems in the Process Industries.

ISCC Vice Chairman

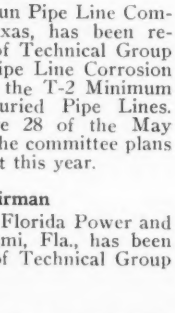
T. J. Maitland has been elected vice chairman of the Inter-Society Corrosion Committee. He is electrolysis and protection engineer with the Long Line Department of American Telephone and Telegraph Co., New York, N.Y.

R. R. Pierce of Pennsalt Chemicals Corporation was elected ISCC chairman (see CORROSION, May, Page 55).

Mr. Maitland and G. W. Seagren of the Mellon Institute of Industrial Research, Pittsburgh, Pa., were reappointed as NACE delegates from NACE to ISCC.



Fenner



Kulman

Maitland

Phillips

Prime

Stewart

Denver Metro Committee Affiliates With T-7D Unit

The Denver Metro Committee on Corrosion has affiliated with NACE's Technical Group Committee T-7, Corrosion Coordinating Committee under Unit Committee T-7D, South Central Region Corrosion Coordinating Committee. This is the 24th group to affiliate with Group Committee T-7.

Officers of the Denver committee are Chairman H. L. Goodrich of American Telephone and Telegraph Co., Denver, Vice Chairman F. F. Hassoldt of the Denver Board of Water Commissioners and Secretary H. A. Emery of the Public Service Company of Colorado, Denver.

Burton to Be T-5 Chairman During Illness of Dillon

W. H. Burton, recently elected vice chairman of Technical Group Committee T-5 (Corrosion Problems in the Process Industries) will be acting chairman of that group for an interim period because of the illness of T-5 Chairman C. P. Dillon of Union Carbide Chemicals Co., Charleston, W. Va.

All correspondence concerning T-5 matters should be sent to W. H. Burton, General Chemical Division, Allied Chemical Corp., Engineering Dept., 1100 Line St., Camden 3, N. J.

Twenty-one Member Groups Report to ISCC

Summaries Presented At General Business Meeting in Dallas

The report of the Inter-Society Corrosion Committee (ISCC), sponsored by NACE, included reports from 21 of the 35 member organizations. The report was presented by outgoing ISCC chairman, K. G. Compton of Bell Telephone Laboratories, Murray Hill, N. J. Incoming chairman is R. R. Pierce of Pennsalt Chemicals Corporation (see CORROSION, May, 1960, Page 55).

The ISCC consists of two delegates from each of 35 U. S. technical, trade and governmental societies and agencies and 13 foreign delegates. Its primary objective is to disseminate corrosion control information to avoid duplicated work. Among its activities is establishment of definitions of terms pertaining to corrosion.

Summaries of some of the reports are given below.

Alloy Casting Institute

The Alloy Casting Institute continued sponsorship of a corrosion program in the Ohio State University Department of Metallurgical Engineering. This program in 1959 included such areas as fundamental research, sigma phase formation in certain alloys, high strength corrosion resistant alloy and several corrosion meetings to discuss work progress.

Electroplaters' Society

The American Electroplaters' Society is continuing three projects on causes and control of corrosion in electroplated metals. These projects are on nature, cause and effect of porosity in electrodeposits, influence of physical metallurgy and mechanical processing of basis metal on electroplating and accelerated corrosion tests for performance of plated coatings.

ASTM Report

The American Society for Testing Materials sponsors corrosion control work by 15 committees, according to the ISCC delegate's report. These included such materials as iron, steel, alloys, cast metals, electrodeposited metallic coatings, structural sandwich constructions, wood, plastics and leather.

ASME Report

Corrosion investigation being conducted by the American Society for Mechanical Engineers includes boiler feedwater studies, corrosion and deposits from combustion gases, effect of temperature on properties of metals and high temperature steam generation.

ASHRAE Report

The American Society of Heating, Refrigerating and Air Conditioning Engineers is distributing questionnaires to manufacturers of room air conditioners to establish corrosion difficulties that have been encountered. After the questionnaires have been collected and analyzed, the ASHRAE hopes the information can be discussed at a meeting to prevent repetition of the corrosion difficulties.

Welding Society

The American Welding Society has a High Alloys Committee which conducts its work under the guidance of ten subcommittees and task forces which cover such areas as field corrosion tests, welding of stainless steel, corrosion resistant castings and interpretation of corrosion characteristics of Types 304 and 304L stainless steel weldments.

Canadian Research Council

The National Research Council of Canada sponsors the Associate Committee on Corrosion Research and Prevention. Part of the committee's work includes a long term atmospheric corrosion test program with 11 metals exposed at 8 sites.

Other reports given by delegates from participating member organizations included meetings on corrosion, technical papers in the field of corrosion control and research programs in progress.

Gleekman Selected to Fill Gribble's Post on Board

L. W. Gleekman, supervisor of materials engineering, Research and Engineering Division, Wyandotte Chemicals Corp., Wyandotte, Mich., has been selected to fill the position as a director representing corporate members which was left vacant by the resignation of C. G. Gribble, Jr., upon his election as NACE treasurer. This term of office expires March 31, 1961.

Mr. Gleekman has been selected by the NACE Nominating Committee to be voted on by the membership as corporate member representative for the term of office from 1961-64.

Executive Committee Members Confirmed By NACE Directors

Members of the NACE Executive Committee for 1960-61 have been confirmed by the board of directors as follows: George E. Best, Manufacturing Chemists' Association, president; Hugh P. Godard, Aluminium Laboratories, Ltd., past-president; Edward C. Greco, United Gas Corp., vice-president; C. G. Gribble, Metal Goods Corp., treasurer; R. McFarland, Jr., Hills-McCanna Co., appointive member. Mr. McFarland is a director representing active membership.

The executive committee makes interim decisions between board meetings and carries out instructions of the board.

Best

Godard

Greco

Gribble

McFarland

One Way to Have Short Section Meeting

The Panhandle Section demonstrated one way to cut the length of time for a section meeting: burn the building down.

At the April 24 meeting of the Panhandle Section, according to the section's secretary-treasurer, J. F. Hendrick, "the meeting broke up immediately after dinner when the building caught fire."

Cause of the fire was not given in the report, but it could not have been from a heated discussion—the speaker didn't even get started.

Though the immediate problem had little to do with corrosion control, the section members and guests assisted the volunteer fire department and helped direct traffic.

This method of holding brief section meetings is effective but very expensive.

Northeast Region

1960 NORTHEAST REGION CONFERENCE committee chairmen are well along with their plans for the October 11-14 conference to be held at the Prichard Hotel, Huntington, W. Va. Seen above in a general planning session are left to right the following chairmen and committee members: William R. Lambert of United Fuel Gas Co., publicity committee; Ralph Felty of Ben Williamson and Co., entertainment committee; Graves H. Trumbo of McJunkin Corp., finance chairman; R. G. Schroeder of Standard Untramarine and Color Co., general conference chairman; George C. Cox, publicity and printing chairman; Robert W. Hinshaw of Banks-Miller Supply Co., assistant to conference chairman; W. G. Mathews of Columbian Carbon Co., chairman of the Kanawha Valley Section; and L. S. VanDelinder of Union Carbide Chemicals Co., technical program chairman. Two other committee chairmen are shown above: Laban T. Moore of Tennessee Gas Transmission Co., registration, and R. P. van Blaricom of Durametallic Corp., plant tours.

Southeast Region

Technical Program Plans Begun for Oct. 6-8 Conference

Tentative technical program for the October 6-8 Southeast Region Conference has been arranged. Items on the technical program are listed below.

The 1960 Southeast Region Conference will be held at the Dinkler-Plaza Hotel in Atlanta, Ga. (See Page 33, April CORROSION, for list of conference committee chairmen.)

Thursday, October 6

1. Pan American film of missile activities at Cape Canaveral.
2. "Thin Tank Linings" by W. P. Cathcart of Tank Lining Corp.
3. "Use of Slag as Aggregate in Concrete" by C. P. Larrabee of U. S. Steel Corp.
4. "Corrosion Problem of Municipal Sewage and Water Treatment Plant" by Perry Cessna of the City of Bradenton, Fla.
5. "Selection of Tube Transmission Materials on Cost Basis."
6. "Twenty-five Years With One Pipe Line" by Fred Stull of Texas Gas Transmission Corp.
7. "Twenty-five Pipelines in One Year" by Henry Allen of Allen Corrosion Corp.

Friday, October 7

1. "Aluminum Steel Wire" by Jane Rigo of American Steel and Wire.
2. "Corrosion Problems of Air Conditioning Systems."
3. "Report on Use of Aluminum Pipe in Underground Installations" by E. T. Wandered of Aluminum Company of America.
4. "Corrosion Problems of Steel Fabricated Fertilizer Plant" by Robert Lukat of Southern Nitrogen Co.
5. "Radiant Heat Reflectance of Exterior Paint Systems" by Raymond Tooke, Jr., of William Rose & Company.
6. "Mill Scale as a Coating Anchor" by Kenneth Tator of Tator Associates.

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Birmingham Section heard James L. Anderson speak on above-ground corrosion at the may 6 meeting.

•

Tidewater Section scheduled H. Lee Craig of Reynolds Metals Co., Richmond, Va., as guest speaker for the May 4 meeting. He gave a review of the 16th Annual NACE Conference and 1960 Corrosion Show in Dallas.

The section's next meeting is scheduled for September 14 in Norfolk.

•

Atlanta Section showed the film "Controlling Corrosion on a Pipeline" at its May 24 meeting.

Research Council Receives NACE Donation of $500

For the second consecutive year, NACE has made a contribution of $500 to the Corrosion Research Council of the Engineering Foundation. The council is sponsoring research into the fundamentals of corrosion processes and has made several progress reports on the work.

Moore

van Blaricom

New Officers Are Elected By Lehigh Valley Section

New officers for the coming year were elected by the Lehigh Valley Section at the March 21 meeting. They are Chairman Seymour C. Frye of Bethlehem Steel Co., Bethlehem, Pa., Vice Chairman Ray Graver of Electro Chemical Engineering & Mfg. Co., Emmaus, Pa., Secretary-Treasurer Donald H. Gittelman of Glidden Company, Reading, Pa., and Member-at-Large William H. Rutter of Electro Chemical Engineering & Mfg. Co., Emmaus, Pa.

Guest speaker at the meeting was Ian Packman who spoke on maintenance and corrosion problems of the New York Port Authority.

The section's annual field trip was held May 13. Bethlehem Steel's Grace Mine was visited.

•

Metropolitan New York Section heard E. H. Thalmann of Ebasco Services, Inc., speak on underground pipe coatings at the May 11 meeting.

•

Greater Boston Section scheduled John Delmonte of Furane Plastics, Los Angeles, Cal., to speak on chemical resistant epoxy coatings at the May 11 meeting.

•

Wilmington Section heard the topic "Use of Thermoplastics for Chemical Process Equipment" discussed by Harvey E. Atkinson at the May 25 meeting.

•

Northeast Region's 1960 Conference will be October 11-14 at the Prichard Hotel, Huntington, W. Va.

SECTION CALENDAR

June

13 Central Oklahoma Section Ladies' Night.
14 Shreveport Section. Annual Barbeque.
14 San Joaquin Valley Section. Maison Joussand's Restaurant, Bakersfield, Cal.

July

6 Teche Section. Petroleum Club.

•

NACE's 18th Annual Conference and 1962 Corrosion Show will be held March 18-22, 1962, at the Municipal Auditorium in Kansas City, Mo.

Treasurer's Report For 1959 Given at Business Meeting

Consistent with past operations, the NACE fiscal year ended with a small difference between income and expense. Income for 1959 from regular business exceeded the budget only slightly. Income from publications and the 16th Annual Conference was slightly less than budget. Regular business, publication and conference expenses were lower than the budget, according to the NACE treasurer's report presented to the Board of Directors.

Membership Growth

Grand total membership in NACE was 6,343 on December 31. This figure has increased considerably since that date.

NACE membership growth included a net increase of 177 active members in 1959 for a total of 5,397. Actually, 843 active members joined during the year, but 666 members resigned or were dropped on December 31 for non-payment of dues. Total junior members is now 36. There was a decrease of 20 in corporate members with a total of 370. The decrease is attributed to the increase in dues affecting those whose dues became due in October, November and December.

NACE Annual Income

Total income for 1959 was $338,318. This is represented by the following incomes: publications, $187,728; conference, $65,556 and regular business, $86,034.

Expenses for 1959

Total expenses for 1959 were $329,963, of which $34,210 was conference expense, $86,850 for regular business and $208,903 for publications.

The difference between expense and income totals is $8,355, which is the 1959 addition to equity. Total association equity as of December 31, 1959, was $216,776. This margin of income over expenses for 1959 is 2.5 percent of total income. The margin has varied from 6 to 2.5 percent during the past five years.

The table below gives the association's condensed balance sheet as of December 31, 1959.

CONDENSED BALANCE SHEET
December 31, 1959

ASSETS

Current assets, total	$182,215
Investments, shares in savings associations	118,000
Special funds	
Educational Fund	1,644
Fixed assets at cost	
Office furniture and equipment	26,786
Less reserve for depreciation	12,469
Fixed assets—net	14,317
Deferred Expense	11,565
TOTAL ASSETS	327,741

LIABILITIES AND ASSOCIATION EQUITY

Current liabilities, total	$ 7,011
Amounts received in advance	85,583
Revenue deferred, total	16,827
Contributions for research and educational purpose, total	1,544
Association equity	216,776
Total liabilities and equity	327,741

President Outlines Goals For Education Committee

NACE President George E. Best has suggested that the Education Committee develop recommendations to draw the attention of young people to the corrosion field as a career, to advance the understanding of non-professional technicians and to enlarge on the appropriate status of the professional and consulting engineers engaged in corrosion control services.

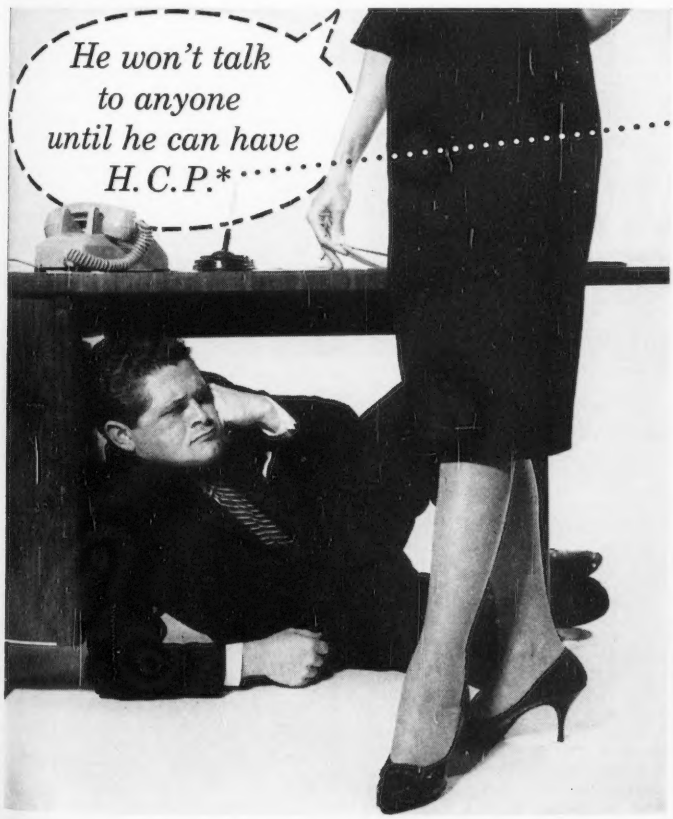
President Best in his letter to the committee also suggested that progress could be made in enhancing and to some extent establishing basic requirements of professional level short courses.

Two new members appointed to the Education Committee are Frank B. Burns of Kerr-McGee Oil Industries, Inc., Wynnewood, Okla., and NACE Vice President Edward C. Greco of United Gas Corp., Shreveport, La.

Chairman of the committee is Norman Hackerman of the Department of Chemistry, University of Texas, Austin. Other members are M. G. Fontana of Ohio State University, Columbus, J. J. Harwood of the Navy Department, Washington, D. C., and R. B. Hoxeng of U. S. Steel Corp., Monroeville, Pa.

Advertising Subcommittee

A. B. Smith, president of Amercoat Corporation, has been appointed a member of the Advertising Subcommittee by R. S. Treseder, chairman of the NACE Publications Committee. J. E. Leoffler of the Thornhill Craver Company, Houston, Texas, is chairman of the Advertising Subcommittee.



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NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1960

Oct. 6-7—10th Annual Western Region Conference, Sheraton-Palace Hotel, San Francisco, Cal.

Oct. 6-8—Southeast Region Conference, Dinkler-Plaza Hotel, Atlanta, Ga.

Oct. 11-14—Northeast Region Conference. Prichard Hotel, Huntington, W. Va.

Oct. 19-20—North Central Region Conference. Pfister Hotel, Milwaukee.

Oct. 25-27—South Central Region Conference. Mayo Hotel, Tulsa.

November 14-16—Eastern Division, Canadian Region Conference, Hotel Royal, Montreal.

November 17-18—NACE Board of Directors Meeting, Sherman Hotel, Chicago, Ill.

1961

March 12—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.

March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.

March 17—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.

Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference and Exhibition, Shamrock-Hilton Hotel, Houston.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

1962

March 19-23—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N. Y.

October 9-11—North Central Region Conference.

October 16-19—South Central Region Conference and Exhibition, Hilton Hotel, San Antonio.

Southeast Region Conference, Birmingham, Ala.

Western Region Conference, San Diego, Cal.

SHORT COURSES

1960

September 12-16—Short Course on Process Industry Corrosion, sponsored by NACE Technical Committee T-5 and Ohio State University, to be held at Ohio State University, Columbus.

September 28-30—Central Oklahoma Section 1960 Corrosion Control Short Course, at University of Oklahoma, Norman.

October 3-5—Corrosion Control Short Course, sponsored by Western Region and University of California, San Francisco.

October 12-13—San Joaquin Valley Section Biannual Corrosion Tour Registration at Bakersfield Inn, Bakersfield, Calif.

Reports Given From 15 Groups Working in Corrosion Control

Reports from 15 NACE representatives to other organizations involved in corrosion control activities were given at the Dallas Conference meeting of the Board of Directors. A summary of these reports is given below.

API Panel on Cooling Water

The API Subcommittee on Corrosion of Refinery Equipment became interested in the problem of deterioration of wood in cooling towers and conducted a short study in which information from other sources was compiled for use by API group members. This compilation of information was done to avoid duplication of work done by other groups.

NACE liaison representative is E. Q. Camp of Humble Oil and Refining Company. The API Subcommittee is cooperating with NACE Task Group T-5C-1 on Corrosion by Cooling Waters (South Central Region).

ASTM Committee on Corrosion Testing Methods

Close liaison has been maintained between NACE Unit Committee T-5E (Stress Corrosion Cracking of Austenitic Stainless Steel) and ASTM Committee A-10, Sub IV on Methods of Corrosion Testing, according to NACE representative M. E. Holmberg, metallurgical consultant.

A joint technical bulletin of about 200 pages will be published by ASTM on the subject of stress corrosion cracking of austenitic stainless steels. It will consist of case history reviews, present status of research on stress corrosion and mechanisms involved, a summary review and an extensive bibliography and tabular data.

Federation of Societies for Paint Technology

The Corrosion Committee of the Federation of Societies for Paint Technology is continuing its evaluation of panels into the second year on the exposure project "Minimum Paint Film Thickness for Economical Protection of Hot Rolled Steel." Results of the second year's exposure showed little change from previous reports, but two paint systems are showing abnormal behaviors which may result in premature failure.

American Welding Society

The American Welding Society's Committee on Metallizing has published a 3-year interim report on corrosion tests on metallized coatings, according to NACE's representative C. P. Larrabee of U. S. Steel Corporation. The AWS committee is working in cooperation with NACE Unit Committee T-6R on Protective Coatings Research.

The AWS committee report covered inspection of specimens removed after three years. Subsequent inspections did not reveal any failures in the atmosphere, thus leading to the conclusion that the spray coatings of zinc and aluminum are giving good protection to the steel panels.

Results of a metallographic examination of the three-year aluminum spray metallized specimens by Hugh P. Godard of Aluminium Laboratories, Ltd., Kingston, Ontario, Canada, and of zinc specimens by Mr. Larrabee were not included in the AWS committee report. This investigation dealt with small blisters which were reported to have formed on the aluminum coated surface. Dr. Godard found that no macro blisters

(Continued on Next Page)

What Kinsolving Said About NACE

The quotation below was extracted from a talk made by William C. Kinsolving, president Sun Pipeline Company and Sun-Canadian Pipeline Company, Philadelphia at a luncheon March 17 in Dallas. Mr. Kinsolving spoke to some 150 representatives of corporate members of the National Association of Corrosion Engineers.

"Perhaps you would like to have my opinion, as representing management, of the work being done by NACE. I have not had an opportunity to review your roster or to know what different industries are represented in your organization. However, I think I am safe in making the statement that no industry in the United States has a greater stake in the study of corrosion and its prevention than does the oil business, and more in detail, the pipe line end of that business. When I tell you that we have over 200,000 miles of petroleum pipe lines in the United States and 163,000 miles of natural gas pipelines, you can see that this one item alone justifies all of the time and money we are spending on this type of work. This is not to mention the miles of oilwell pipe, above and below ground steel storage, marine docks and installations, tankships, refinery equipment, and other corrodible structures. In other words, the oil industry floats on a sea of steel.

The problems of corrosion and the methods used to mitigate them are too manifold for any one industry group of corrosion engineers to research alone and it is only through the combined efforts and exchange of ideas in such a group as NACE that we are able to pool our information and get the benefit of the combined brains of this group. Many associations are purely trade associations. I feel that a group such as this is much more effective because it is a collection of highly skilled scientific brains working collectively on a common problem.

From the above I think you can infer that management, at least as far as I am concerned, is heartily in favor of your work."

EDITOR'S NOTE: Mr. Kinsolving's speech may be obtained by writing to T. J. Hull, Executive Secretary, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

were found on the aluminum sprayed steel specimens and that three types of discontinuities existed on the specimens: small bare steel areas with no aluminum coating, lamellar separation within the aluminum coating and separation of aluminum coating from the steel. These discontinuities were of micro dimensions.

Mr. Larrabee reported that examination of zinc panels from atmospheric and sea water exposures showed particles of zinc oxide in the interstices, but in no case did these extend to the steel.

ASCE Committee on Pipeline Crossings

NACE's representative to the American Soicety of Civil Engineers' Committee on Pipelines Crossing Railroads and Highways, Sidney E. Trouard of New Orleans Public Service, Inc., reported on the committee's February meeting. Thirty-five were present, representing railroads, highway commissions, oil pipeline companies, gas transmission and gas distribution companies, material suppliers, Bureau of Public Roads, Federal Power Commossion and NACE.

Charged with the responsibility of writing proposed specifications for pipeline crossings of railroads and highways, the committee is working to resolve the problem of whether casings prevent cathodic protection of the carrier pipe.

Liaison With Other Groups

NACE has representatives with other organizations and groups which include the following:

ASTM Joint Committee on Chemical Analysis by Powder Diffraction Methods, ASTM Committee D-19 on Industrial Water, Society of the Plastic Industry, Steel Structures Painting Council, Construction Specifications Institute, API Division of Refining Subcommittee on Corrosion, National Research Council's Subcommittee on Corrosion, American Standards Association's Sectional Committee N-5 (Chemical Engineering in the Nuclear Field) and the Inter-Society Corrosion Committee (see accompanying story on this page).

Canadian Region

Edmonton Section heard Bud Seager of Interprovincial Pipe Line Company speak on external coating for pipe lines at the April 28 meeting.

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Certificates for past chairmen of regions and sections, measuring 9 x 12 inches, are available from the Central Office at $7.50 each.

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In the petroleum industry, ALCOA Aluminum Tubes serve in main column overhead condensers where their freedom from fouling and excellent heat transfer properties have made them a natural selection. Heat exchangers made of ALCOA Aluminum Tube and Plate are used in the production of ammonia, nitric acid, vegetable oils, naval stores, naphthalene, hydrogen peroxide, oxygen and urea. These and other processes call for heat exchangers with combinations of high strength, excellent sub-zero physical qualities, high thermal conductivity, or nontoxic and noncatalytic properties. ALCOA Aluminum alloys meet all these requirements.

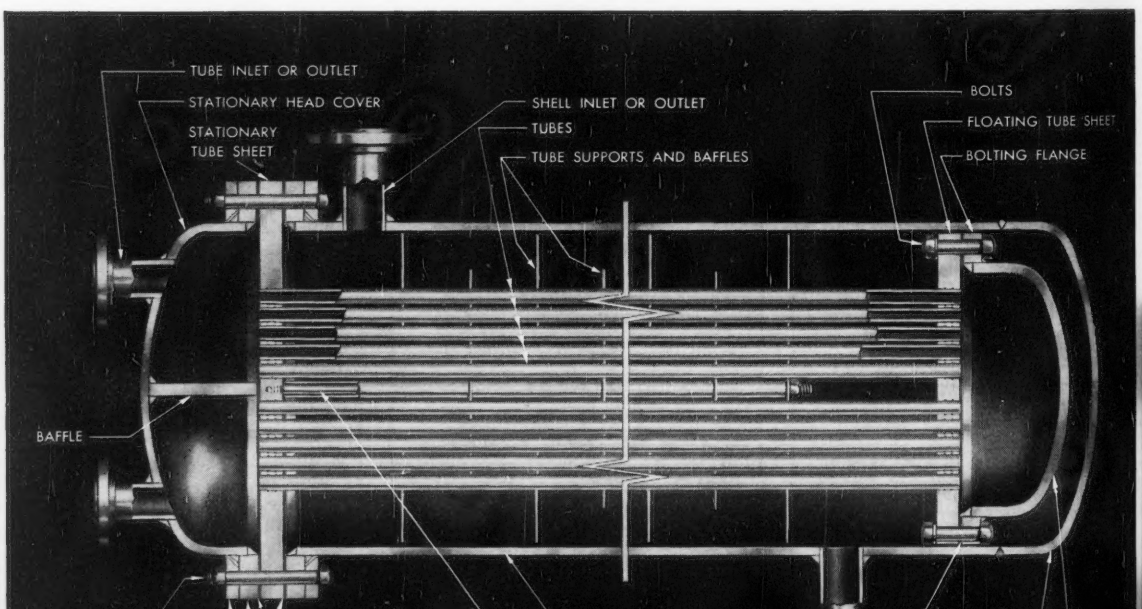
As for cost, ALCOA Aluminum Tube is the most inexpensive. In the common sizes it costs one-third less than mild steel, one-half as much as admiralty, and one-fifth that of stainless.

ALCOA Aluminum alloys are ideally suited to a wide range of maintenance methods. For relatively soft or loose scale, water jets and brushes are usually satisfactory. Wet sandblasting as well as chemical cleaners may be used effectively.

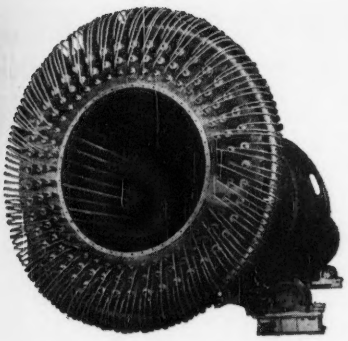
ALCOA engineers have worked closely with all segments of the process industries for over 40 years, and can help you specify the aluminum alloy best suited to your heat exchanger and other process applications. ALCOA's unparalleled experience in this field is available to you for the asking. Write to the address on the coupon, stating your requirements as specifically as possible. ALCOA's development engineers will welcome the opportunity to work with you on your problems.

You can also take advantage of the wide selection of free ALCOA literature on aluminum for heat exchangers and other process applications. Simply check the booklets you want on the coupon and mail to the address indicated. ALCOA will forward your material promptly and without obligation.

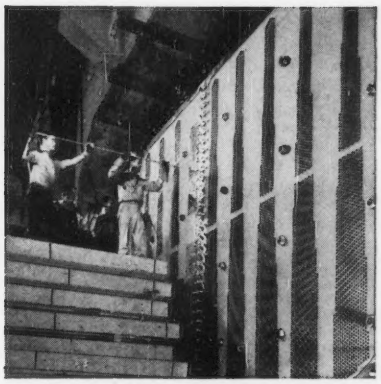
ALCOA is conducting a series of engineering conferences on process industries applications of aluminum during 1960 in a number of major cities. Contact your nearest ALCOA sales office for full particulars and dates.



For certain processes where corrosive or sensitive materials are involved, it is often advisable to use aluminum for entire heat exchanger systems to avoid system corrosion and contamination of the product. A typical all-aluminum heat exchanger is shown here. Alloy recommendations are given in the table opposite.

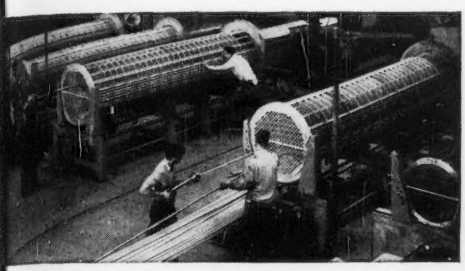


Alcoa Aluminum Tubing protects color in the world's largest rotary steam-tube drier. The drier measures 10 ft in diameter by 100 ft long.

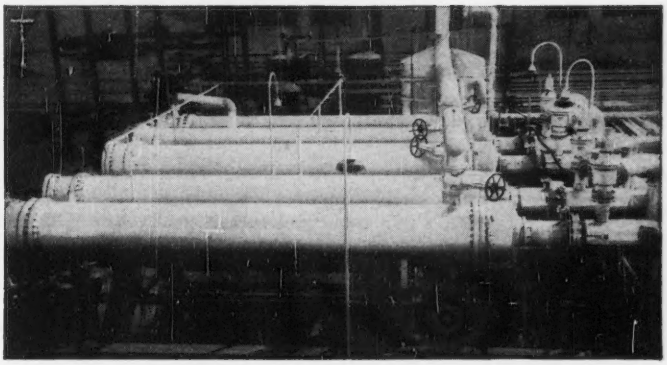


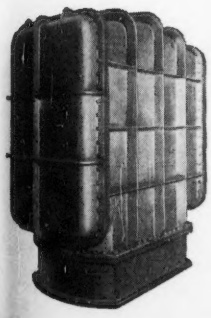
A Midwest utility saved 50 per cent on tubing costs by using Alcoa Aluminum instead of admiralty for tubing in this surface condenser. Successful operation of this unit has led to the installation of similar units by other utilities. This use demonstrates aluminum's economy and superior resistance to ammonia, carbon dioxide and hydrogen sulfide.

A battery of all-aluminum heat exchangers in a polyethylene plant. Selected for initial low cost, these aluminum exchangers provide freedom from product contamination as well as desirable low temperature properties.



Construction of a heat exchanger utilizing Alcoa Aluminum Tube. Superior working properties plus the cold-drawing method by which Alcoa seamless heat exchanger tubes are produced results in close dimensional tolerances and smooth inside and outside surfaces.





This all-aluminum dephlegmator in a large coke plant is used for the regeneration of ammonia liquor in a hydrogen sulfide scrubbing operation. Aluminum tubes lasted five times longer than steel tubes in a similar use.

Alloy Recommendations for Aluminum Heat Exchanger Construction

	Alcoa Designation	ASTM Specification*	Alloy
Tubes	3003-H14	B234	M1A
	Alclad (inside) 3003-H14	B234	clad M1A
	Alclad (outside) 3003-H14		clad M1A
	Alclad (both sides) 3003-H14		clad M1A
	6061-T6	B234	GS11A
	6062-T6	B234	GS11C
Tube Sheets	3004-H112	B178	MG11A
	Alclad 3004-H112	B178	clad MG11A
	6061-T6	B178	GS11A
	Alclad 6061-T6	B178	clad GS11A
Baffles	3003-H14	B178	M1A
	Alclad 3003-H14	B178	clad M1A
Tie Rods	6061-T6	B273	GS11A
Shells & Headers	3003-H112	B178	M1A
	Alclad 3003-H112	B178	clad M1A
	3004-H112	B178	MG11A
	5052-H112	B178	GR20A
	5154-H112	B178	GR40A
Fittings	3003-F	B274	M1A as applicable
	6061-T6	B274	GS11A as applicable
Flanges	6061-T6	B247	GS11A as applicable

*Only the basic number is shown since Alcoa products are manufactured to the latest issue of the specification. The complete number would indicate the year of issue.

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Please send me the following literature covering Alcoa Aluminum for product transfer and other uses in the process industries:

- ☐ 10197 Aluminum Pipe and Fittings
- ☐ 10418 Alcoa Unitrace: Combines Piping and Tracing in One Unit
- ☐ 10270 Alcoa Utilitube
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 11453 Solving Refinery Corrosion Problems with Aluminum
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
- ☐ 19416 Brazing Alcoa Aluminum
- ☐ 10415 Welding Alcoa Aluminum
- ☐ 19051 Alcoa Aluminum Handbook

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Western Region

Seventeen Symposia Planned for 1960 Region Conference

Papers are being scheduled in seven technical symposia for the 1960 Western Region Conference set for October 6-7. This 10th annual conference will be held at the Sheraton-Palace Hotel in San Francisco.

Tentative titles of papers scheduled and their authors are given below for each of the seven symposia.

(See Page 64, May CORRISON for photographs and list of Western Region Conference chairmen.)

A short course in corrosion control will be held just preceding the conference. (See accompanying story on this page.)

General Corrosion

1. Movie: "Stress Corrosion of Stainless Steel," produced by Mars G. Fontana, Department of Metallurgical Engineering, Ohio State University.
2. "Stress Corrosion of Stainless Steel" by Richard A. White of Standard Oil Company of California.

Nuclear and Missile Industry

1. "Stress Corrosion of 410 Stainless Steel in Fuming Nitric Acids" by L. L. Gilbert of Aerojet-General Corp., Azuza, Cal.
2. "Corrosion of Nickel Base Alloys in High Temperature Nitrogen Environments" by G. W. Titus and J. S. Brunhouse of Aerojet-General Nucleonics, San Ramon, Cal.
3. Paper to be scheduled.

Petroleum Processing

1. Sulfur in Flue Gas Corrosion" by Paul D. Miller, Earl L. White and Warren E. Berry of Battelle Memorial Institute, Columbus, Ohio.
2. "Service Experiences in a Catalytic Desulfurizer Fired Heater—9 Chrome Tubing, Stress Rupture, Heat Treatment in Place" by E. H. Ehmke of Tidewater Oil Co., Associated, Cal.
3. Paper by G. R. Prescott of C. F. Braum & Co., Alhambra, Cal.

LOCAL PUBLICITY for the April 27-29 Portland Section Corrosion Control Short Course included a TV interview with George Silkworth (left in Photograph) of El Paso Natural Gas Co., Yakima, Wash., one of the lecturers at the short course. The interview was conducted on television by Wallace Turner (right) of Station KPTV, Portland. All radio stations carried announcements on the course, and publicity stories appeared in both local papers. Total registration was 149 for this first corrosion control short course held in Oregon.

Coatings, Linings and Plastics

1. "Thick Film Coatings" by William Hodges and John Bogner of Hodges Chemical Co., Montain View, Cal.
2. "Unique Applications for Plastics in Industry" (discussion of plastics for emergency repairs) by Claude B. Smith of Claude B. Smith Co., Oakland, Cal.
3. "Discussion of a Large PVC Pipe Installation" by G. Sorell of M. W. Kellogg Co., New York, N.Y.
4. "San Francisco - Oakland Bay Bridge Story" (details of maintenance through the years) by Dale Downing of San Francisco-Oakland Bay Bridge Toll Plaza, Oakland, Cal.
5. "Maintenance Painting—How to Keep Your Original Surface Preparation and Prime Coat" by Frank T. Radecke of Shell Oil Co., New York, N.Y.
6. "Development of Pre-stressed Ceramic Liners for Chemical Process Equipment" by R. R. Pierce of Pennsalt Chemicals Corp., Natrona, Pa.
7. "New Materials for Coatings" by Paul Christianson of Walter N. Boysen Co., Oakland, Cal.

Chemical Industries

1. "Problems in Pilot Plant Corrosion Testing" by Richard S. Treseder of Shell Development Co., Emeryville, Cal.
2. "Effects of Molding Materials on Corrosion Resistance of Alloy Castings" by Dean D. Burgan of Electric Steel Foundry Co., Portland, Ore.
3. Paper to be scheduled.

Water Treatment and Inhibition

1. "Passivation of Metal Surfaces by Inorganic Inhibitors in Water Environments" by E. R. Duffek of Stanford Research Institute, Menlo Park, Cal.
2. "Passivation of Metal Surfaces by Organic Inhibitors" by R. A. Powers of Union Carbide Consumer Product Co., Cleveland, Ohio.
3. Paper by D. R. Boies, Nalco Chemical Co., Chicago, Ill.

Underground Structures

1. "Cathodic Protection Fundamentals With Practical Applications" by Lindsay M. Applegate of Oregon State College, Corvallis, Ore.
2. "Zinc Ground Rods in Lieu of Copper in an Impressed Current System" by J. D. Ghesquiere of Hinchman Corp., Detroit, Mich.
3. "Design, Construction and Operation of Underground Corrosion Control Systems—Glasgow AFB" by Robert T. Mercer, consulting engineer, Seattle, Wash.

•

Los Angeles Section scheduled an informal review of interference testing techniques used in Kettleman Hills for the May 18 meeting. Speakers were Fred Small of Standard Oil Company of California and F. W. Schremp of California Research Corporation.

•

Portland Section held a dinner meeting April 14 to complete plans for its Corrosion Control Short Course held April 27-29 (see accompanying photograph).

•

Western Region's 1960 Conference will be Oct. 6-7 at the Sheraton Palace Hotel in San Francisco, Cal.

Oct. 12-13 Corrosion Tour Scheduled by San Joaquin

The 1960 San Joaquin Valley Section Biannual Corrosion Tour has been scheduled for October 12-13. The tour will stress visible results of corrosion inhibition in gasoline plants and production facilities, test results of various plastic coatings, special corrosion problems and their correction and some features on cathodic protection.

Registration fee will be $15, including 2 lunches and a luau at the Bakersfield Inn at the conclusion of the tour.

The tours of the San Joaquin Valley oil fields will include trips to Taft and Bakersfield.

Corrosion Short Course to Precede Fall Conference

A short course in corrosion will be held October 3-5 in San Francisco, Cal., immediately preceding the Western Region Conference (October 6-7). The course will be sponsored by the University of California at Berkeley, the University of California at Los Angeles and NACE.

Sessions will emphasize four areas: (1) corrosion fundamentals, (2) introduction to solid state theory in corrosion, (3) corrosion in nuclear reactors and (4) corrosion in process industries.

Information on registration and fees can be obtained by writing I. Cornet, University of California, Engineering and Sciences Extension, 2451 Bancroft Way, Berkeley 4, Cal.

North Central Region

Cleveland Section had two speakers for its May 17 meeting. Douglas J. Kelly discussed corrosion prevention with elastomers. John J. McEvoy talked on the Neoprene-Hypalon roofing system. Both speakers are from duPont's Wilmington Elastomers Laboratory.

•

Chicago Section heard M. L. Monack of the duPont Company speak on "A Chemical Company's Program to Reduce Painting Costs" at the May 17 meeting.

•

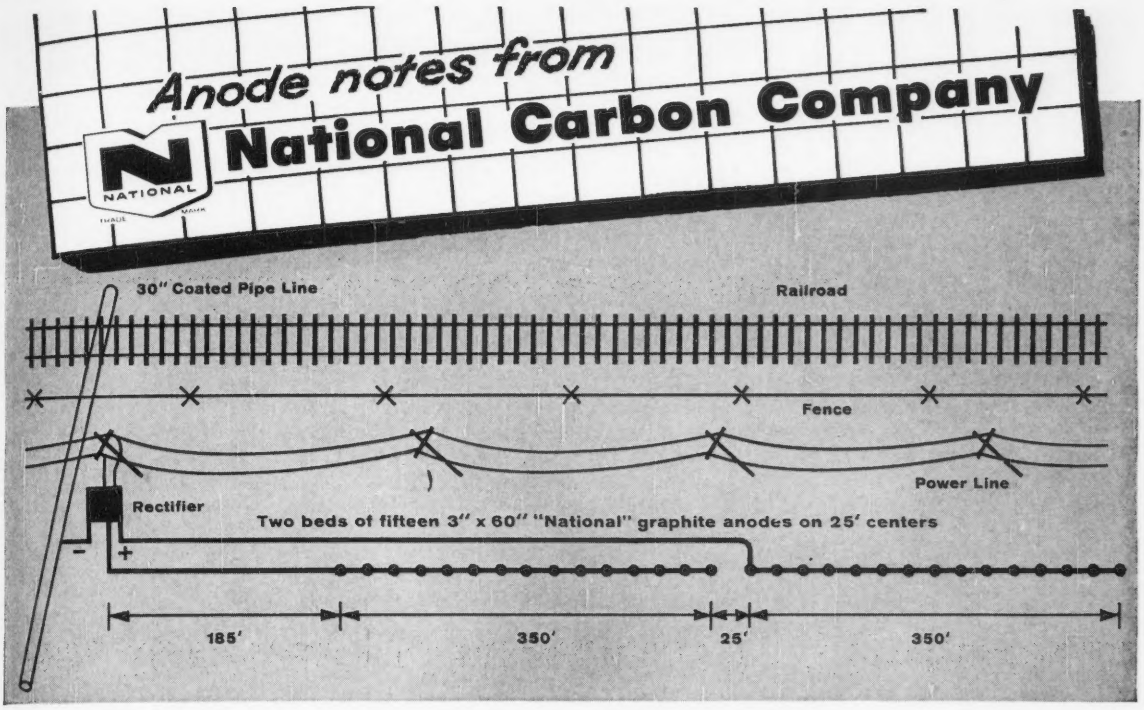
Kansas City Section had the second of a series of programs on underground and above ground coatings at the May 9 meeting. Speakers were R. Robertson of Seidlitz Paint Co., W. Moore of Pittsburgh Coke and Chemical Co., C. Wakefield of Amercoat Corporation and K. E. Meinert of Cook Paint Co.

•

Southwestern Ohio Section made an inspection trip to the Roots-Connersville Blower company plant as part of its April 28 meeting. The evening speaker, Elwood Norris of Metcutt Research Associates, Inc., spoke on evaluation of coatings for protection of steel at elevated temperatures.

•

Detroit Section had a forum discussion on non-destructive testing for corrosion control at the May 19 meeting. Speakers were W. Rolfe of Magnaflux Corp., B. Galloway of Sperry Corp., G. Woods of Nuclear X-Ray Corp., and J. Bobbin of Branson Instruments, Inc.



PROTECTION OF 645 MILES OF 30 INCH COATED STEEL PIPE LINE

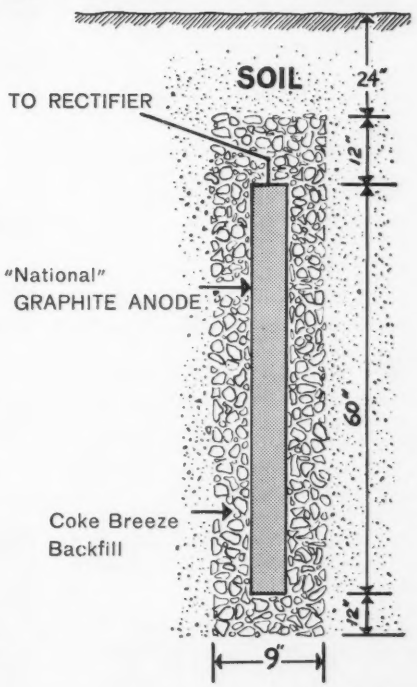
In 1954 the management of a large oil company decided to protect part of their new transmission system. Since time was short they decided to contract for a turnkey cathodic protection job.

The contractor's* corrosion engineers surveyed the entire line and installed eighteen 24 volt rectifiers with 10-20 amp capacity to power the associated "National" graphite anode beds. The beds had from ten to fifty 3" x 60" graphite anodes in coke breeze backfill on 25 ft. spacing.

After the system was energized in 1955, the corrosion engineers tested and made necessary bonds with over 60 "foreign owned" pipe and cable crossings and adjusted the entire system to provide a potential of —.85 volts pipe to soil potential over its entire length.

A complete survey in 1959 showed that the anode beds are all performing satisfactorily. Several new "National" graphite anode beds will be installed to protect additions to the original pipe line. For data on graphite anodes, contact National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York. In Canada, Union Carbide Canada Limited, Toronto.

*Harco Corporation, Cleveland, Ohio



"National", "N" and Shield Device, and "Union Carbide" are registered trade-marks for products of

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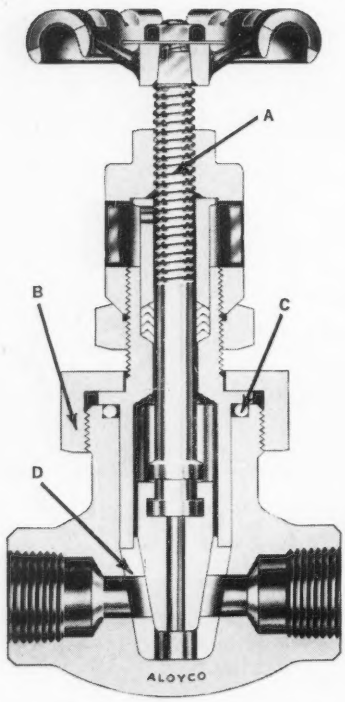
UNION CARBIDE

Aloyco Plug Gate Valve #66 succeeds with severe corrosives for 10 straight years!



Shown ⅔ actual size of the half-inch valve

WHY? **A. OUTSIDE STEM THREADS** are away from corrosive area, prevent galling.
B. UNION BONNET provides extra strength and easy disassembly.
C. O-RING made of "Teflon"* provides tough, leak-proof seal.
D. SEATS made of "Teflon"* are pressure-tight, dependable, won't gall. Renewable.
STAINLESS STEEL: 18-8S, 18-8SMo, Aloyco 20.

FOR: Instrument lines, small lines handling viscous fluids, or where low pressure drop is important.

FACTS: full-floating plug disc exerts no twisting action on the removable seat in closing. Aloyco Stainless Steel #66 Plug Gate Valve: 1200 lb. at 150 F.; 600 lb. at 500 F. Sizes: ⅛", ¼", ⅜", ½". Want more? Write: Alloy Steel Products Company, 1304 West Elizabeth Ave., Linden, New Jersey. O.5

*Registered DuPont Trademark

Longer Lasting ALOYCO VALVES SET IN CORROSIVE SERVICE

ALLOY STEEL PRODUCTS COMPANY

South Central Region

Tulsa Conference to Have Six Half-Day Technical Symposia

Six half-day technical symposia will be held at the 14th Annual South Central Region Conference, October 25-28 at the Mayo Hotel, Tulsa, Okla. The symposia will cover these areas: oil and gas pipeline, chemical processing and refining, water handling, corrosion survey and testing, oil and gas production and protective coatings and plastics.

Conference Committee Chairmen

Richard Lembcke of Cities Service Research and Development Company is general chairman of the conference. His vice chairman is Parke D. Muir of Dowell Division of Dow Chemical Company.

Co-chairmen of the technical program are J. P. Barrett of Pan American Petroleum Corporation and J. N. Hunter of Service Pipe Line Company.

Other committee chairmen pictured on this page are as follows:

R. A. Walton of Royston Laboratories, Inc., properties and projection; L. A. Hugo of Phillips Petroleum Co., finance; S. E. Bosley of S. E. Bosley Co., registration; Guy F. Williams of Dowell Division, Dow Chemical Co., publicity; John M. Taylor, Jr., of Pan American Petroleum Corp., printing; James A. Rush of Nalco Chemical Co., local arrangements; John H. Hoff of Reilly Tar and Chemical Co., housing; Robert M. Nee of Nee and McNulty Inc., entertainment; and Mrs. T. D. Williamson, Jr., ladies program.

New Orleans Section heard Charles M. Hudgins, Jr., of Continental Oil speak on corrosion problems in use of dense salt solutions as packer fluids at the April 25 meeting.

Resin combinations as vehicles for coatings was discussed by L. A. Martin of Humble Oil & Refining Co., Houston, at the March 28 meeting.

(Continued on Page 74)

Barrett

Bosley

Hoff

Hugo

Hunter

Lembcke

Muir

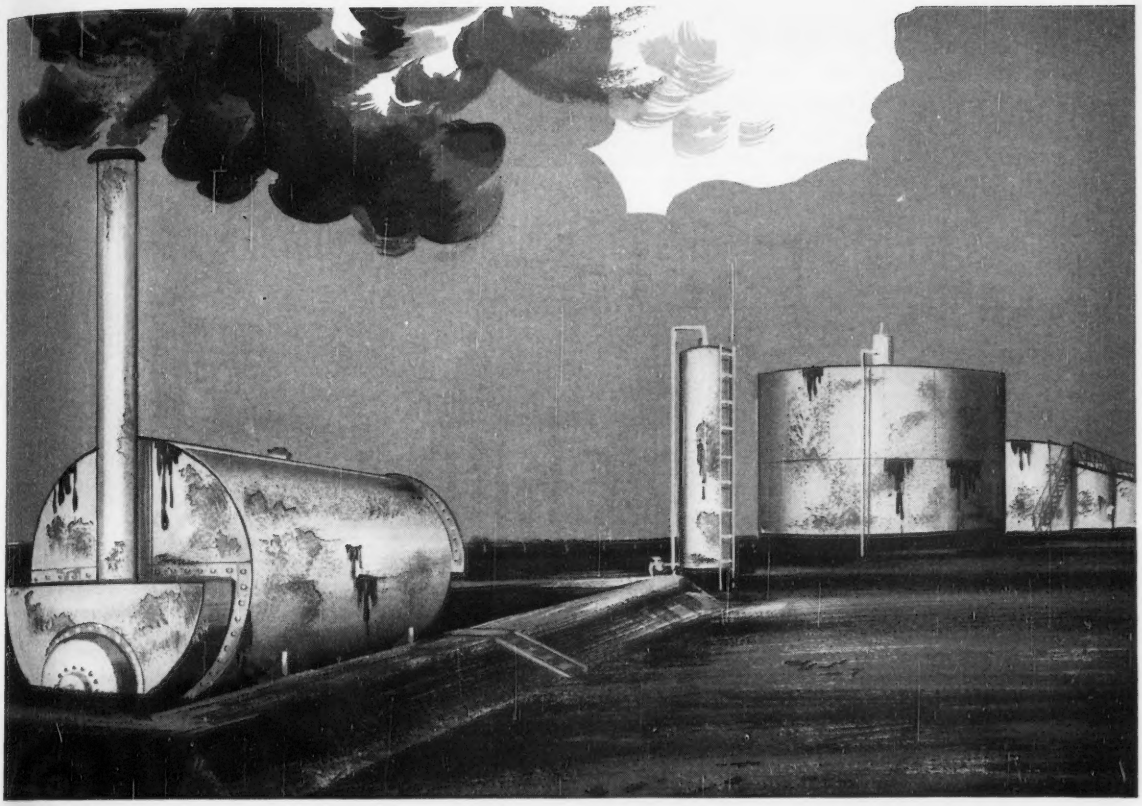
Rush

Taylor

Walton

Williams

Williamson



Is your equipment going up in smoke too?

CPS Heater Treater Cathodic Protection will prevent this loss.

INTERNAL CORROSION of oil field equipment, handling produced brine, can be entirely eliminated by the application of soundly engineered cathodic protection installations. Vessel equipment does not wear out — it corrodes out.

Either your nearest CPS branch office or our home office is readily available for engineering consultation to . . . properly design your cathodic protection systems.

CPS Heater Treater cathodic protection equipment can be procured through your nearest Tank Company — our home office or any of our listed branches.

CPS has also been involved in the engineering and installation of cathodic protection of several thousand well casings and is presently engaged in the installation of cathodic protection on over 500 casings for a Unit Operator in West Texas.

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AMCHEM Information Bulletin

Facts about pickling acid inhibitors

Nearly 40 years ago Amchem developed the first pickling acid inhibitor—RODINE—and with it revolutionized acid pickling. Only a few of the steel mills of the time believed that the addition of less than one percent RODINE to a sulfuric acid pickling bath could save substantial amounts of acid and metal, while increasing the life of the bath. Today there is no mill chemist who does not know about RODINE and its proven performance in eliminating waste of valuable metal and acid, and its ability to pay for itself through the savings thus gained.

In the past few years much attention has been focused on the use of wetting agents to accelerate pickling. But the fact remains that pickling cycles cannot be reduced by the use of wetting agents alone without severe overpickling problems. Wetting agents do help the acid run off surfaces removed from pickle baths, and, in so doing, reduce carry-over of acid into the rinse.

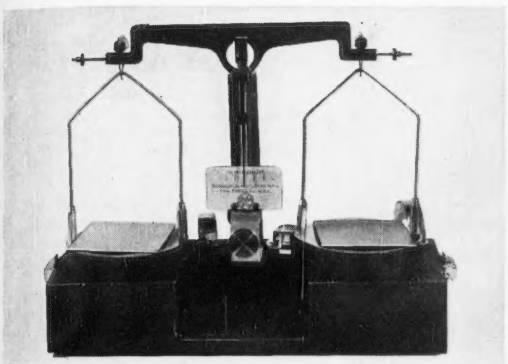
Wetting agents should not be confused with inhibitors to protect the metal and save acid wasted in pitting it. They should not be expected to miraculously speed the removal of scale, even at the expense of wasting the metal. However, the *proper* combination of *real inhibitor* plus correct wetting agent can have beneficial effects on pickling practices.

Only a true inhibitor such as RODINE can offer steel producers solid advantages in pickling. Baths can be operated longer and less acid is required to keep them at desired concentration. Costs of charging and cleaning the bath are reduced, less handling and storing of acid is required. A RODINE bath produces far fewer rejects—steel emerges with uniformly smooth, bright clean surfaces, free of pits, blisters and smut.

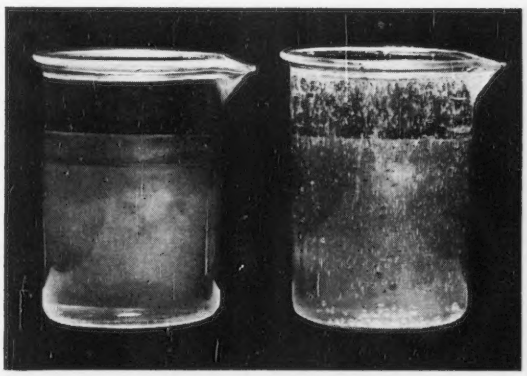
When an Amchem Technical Representative enters your pickle house, you can be assured of experienced assistance in improving your pickling. He will recommend the proper RODINE to 1) prevent needless consumption of acid after scale removal, 2) prevent smutting, pitting and overpickling, 3) produce a stable, free-rinsing foam blanket, 4) improve rinsability and reduce carry-over, and 5) produce a brighter, cleaner surface. Only the Amchem Representative can do this for you because he has at his command the most widely diversified and accepted line of real inhibitors and correct wetting agents available.

Since the early days of pickling acid inhibitor development, scientists in the Amchem Metal Protection Laboratories have constantly studied methods to make the RODINES stronger, more effective and more economical to use. The RODINES of today, as of 40 years ago, are in a class by themselves, have developed a reputation as *the international standard* in acid pickling inhibitors. The fruit of these years of laboratory research and experience in a highly specialized field, and the assistance of Amchem's trained field representatives—specialists in acid pickling techniques—are at your disposal for the asking.

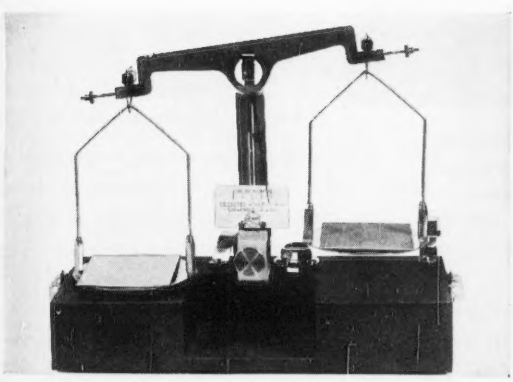
How Rodine Retards Acid's Attack on Metal



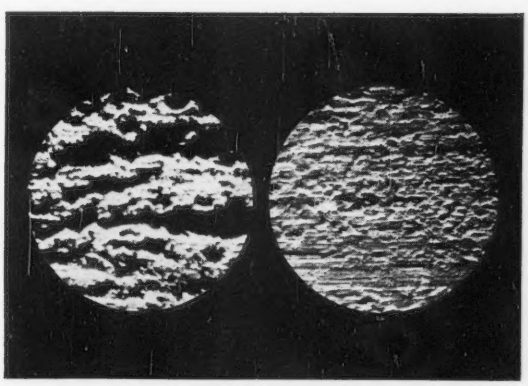
The photographs and microphotographs displayed on this page represent a graphic description of results demonstrating the effectiveness of RODINE in retarding the attack of acid on the metal. NO WEIGHT DIFFERENCE—two identical panels of low-carbon steel are shown being weighed here. They balanced the scale.



RODINE MINIMIZES ACID ATTACK—Each descaled panel was placed in a beaker containing 10% by volume of 66° Bé sulfuric acid of 160° F. The acid in the right-hand beaker was uninhibited. Acid in left-hand beaker was inhibited with RODINE 82, ¼% by volume of the concentrated acid. There was little or no hydrogen evolution in this beaker . . . RODINE retarded the attack of the acid on the base metal.



RODINE SAVES METAL—Both descaled panels were removed from the acid pickle solutions after 5 minutes. The one pickled in the uninhibited acid had lost 1.4% of its original weight. The one pickled in the RODINE-inhibited acid had lost only 0.001% of its original weight. This represents a saving of 26 lb. of steel for each ton pickled; and a simultaneous saving of nearly 50 lbs. of 66° Bé sulfuric acid when RODINE is used to inhibit the acid.



EFFECT OF UNINHIBITED ACID ON THE PANEL — This microphotograph of the low-carbon sheet steel pickled in the uninhibited acid shows deep pits and the crystalline character of the surface after 5 minutes in the solution.

EFFECT OF RODINE-INHIBITED ACID ON THE PANEL — This panel was pickled for 5 minutes in the RODINE-inhibited acid, then microphotographed. Only scale pockets and roll marks are visible; no pitting of the low-carbon sheet steel occurred.

AMCHEM RODINE

Amchem and Rodine are registered trademarks of **AMCHEM PRODUCTS, INC.** (Formerly American Chemical Paint Co.)
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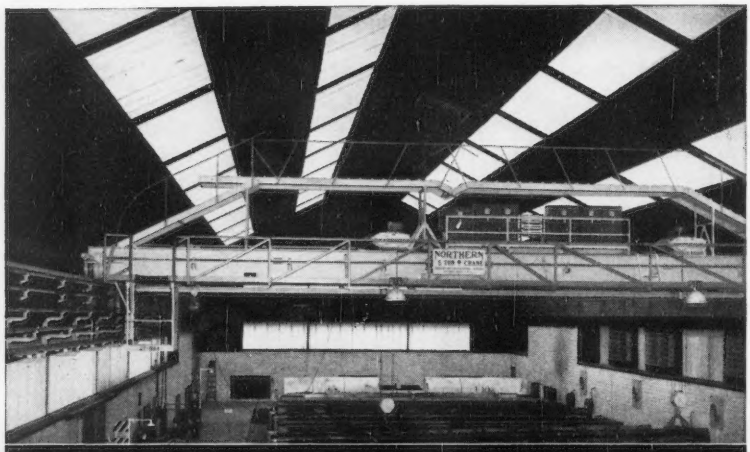


RESOLITE Fire-Snuf® Translucent Panels provide daylight . . . plus . . . help solve corrosion problem at International Nickel

This new cold drawn pickling house at the Huntington, West Virginia, works of International Nickel Company is an unusual and interesting application of corrosion-resistant material. The fact that all structural members, including even light fixtures, are outside the building shell, illustrates imagination in design.

Four rows of RESOLITE Fire-Snuf® Translucent Panels are installed in the roofing area to admit daylight. For night lighting the lights themselves are directed through the panels. Additional RESOLITE panels are used in the side and end walls. All material is treated with Super Hard Coat for long-lasting, maintenance-free life.

Here is another unusual application where RESOLITE engineers helped solve a corrosion problem. For additional information on RESOLITE Fiberglass Panels for industry write . . .

Engineering Specialists in Reinforced Polyester Panels

RESOLITE CORPORATION

P. O. BOX 539, ZELIENOPLE, PA.

DISTRIBUTORS IN PRINCIPAL CITIES

1945-55 Back Issues To Be Available In Bound Volumes

Bound volumes of back issues of CORROSION for the years 1945-55, inclusive will be made available as result of an agreement made during May. The National Association of Corrosion Engineers has signed a contract with Johnson Reprint Corporation, 111 Fifth Ave, New York 3, N. Y. providing for issuance by the reprint company of bound volumes of CORROSION. This will satisfy the recurring demand for complete sets of CORROSION which NACE presently is unable to fill.

Under the agreement Johnson will reprint out-of-stock issues, compile full volumes of CORROSION and offer them for sale. The corporation presently is offering a similar service for other technical publications.

Johnson also will attempt to fill orders for single issues of CORROSION. Persons who have back issue files they no longer need may find ready sales for their back issues to the corporation.

NACE will continue to supply both complete volumes (when available) and single issues for the years 1956 to date. NACE also will supply single copies of articles by photofacsimile and multiple reprint copies of all articles.

NACE Contribution Made

A contribution of $250 has been made by NACE to the Steel Structures Painting Council for 1960. This contribution continues the practice of the last several years.

South Central Region

(Continued From Page 70)

Greater Baton Rouge Area Section scheduled a talk on seamless stainless steel pipe versus welded pipe for the May 23 meeting. Guest speaker was Joe Harkins of Carpenter Steel Company.

E. C. Warner of Akron Sandblast & Metallizing Company presented a paper on sprayed metal as a base for protective coatings at the April 18 meeting.

•

Teche Section had 31 members and guests at its May 4 meeting. Victor F. Hajovsky, Jr., of Plastic Applicators, Inc., Houston, spoke on economics in the use of plastic coatings.

•

Corpus Christi Section held a panel discussion on several areas of corrosion control for the April 26 meeting. B. P. Ledbetter was panel moderator.

•

East Texas Section heard H. I. Dedman of Lone Star Steel speak on quality control of steel tubular goods at the April 26 meeting.

•

Houston Section will have four panel speakers discuss inhibitor testing and evaluation at the June 14 meeting to be held at the Houston Engineering Society Banquet Room.

•

North Texas Section held its annual "Ladies' Night" meeting on May 9. The program was on education improvement in the community.

Directors Accept Planning Committee Fund Recommendation

A recommendation on reimbursements and advances of funds to regional divisions and sections was presented to the NACE Board of Directors by R. A. Brannon, chairman of the NACE Policy and Planning Committee, during the Dallas Conference.

Mr. Brannon said his committee recommended to the directors that Paragraph 3 of Section IV of the Procedure for Reimbursements and Advances of Funds From Central Office to Regional Divisions and Sections and for Annual Reports be deleted from the Procedure. Paragraph 3 is as follows:

"Association funds in the hands of Regional Divisions and Sections shall not be accumulated by such organizations to any amount greater than that which they would be entitled to use in any fiscal year. If at the end of any fiscal year the activities of the organization have not required the use of the funds advanced by the Association, the Secretary and Treasurer of the Association shall reduce the net amount allowable to such organization in the subsequent year to the sum needed to restore the funds to the authorization for said subsequent year."

Mr. Brannon explained that all funds in the hands of the regional divisions and sections are considered Association funds. No attempt has been made to define the amount to which any region or section would be entitled to use in any fiscal year. For this reason, the association's executive secretary has found it impossible to interpret and apply the paragraph, he said, and in the opinion of the Policy and Planning Committee it should be deleted from the Procedure.

The Board of Directors voted that the committee's recommendation be accepted.

Over 215,000 Committee Reports Circulated in '59

Over 215,000 copies of NACE technical committee reports were circulated in 1959 according to the report of the Technical Practices Committee given by Chairman T. J. Maitland, American Telephone & Telegraph, New York, N. Y., before the NACE Board of Directors during the Dallas Conference in March.

Total membership in technical committees is 1445, a growth of 200 percent during the past six years. Twenty-five new activities were begun in 1959 including five new unit committees and 20 new task groups.

In addition to holding meetings at the annual conference, 35 technical committees held meetings during the five regional conferences in the fall. This included six meetings during the Northeast Region Conference, six at the North Central Region, 21 at the South Central Region and 2 at the Western Region. Three unit committees have been holding monthly meetings.

Two Sets of Back Issues Available From Individuals

Two sets of back issues of CORRISON Magazine are available from an NACE member and a former member.

One set includes all issue of the magazine from the first issue in 1945 to January, 1960, bound in 14 volumes. The binding is blue buckram with gold lettering on the book spine. Advertising has been deleted from all the issues except those for December, the index issue for each year. Persons interested in purchasing this set of back issues should contact Ansel L. Conns, 3159 South Stafford St., Arlington 6, Va.

Former NACE member C. R. Goodrich of 127 W. Woodlawn Ave., San Antonio, Texas, has all issues of CORROSION since January, 1948, available for any person interested.

NACE Board Must Authorize All Awards for Association

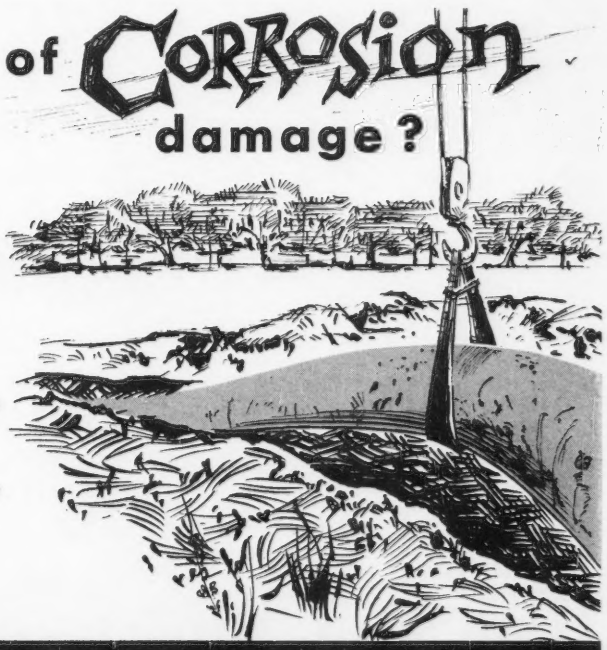
Awards made in the name of NACE or any of its subdivisions must be authorized by the board. The NACE Executive Committee was given responsibility for implementing the new rule, which will be incorporated in the association's by-laws.

NACE also discourages conferring certificates by holders of short courses and suggests that, if conferred, they should refer to attendance only.

•

In 1959, 50,000 swimming pools were built in the United States. Only 17,000 of these were for use by clubs.

feeling the effects of CORROSION damage?



Midwestern's Keystone Keybestos Felt is one sure way to better protect your pipelines from costly failures due to corrosion damage. Keybestos provides a tough, durable wrapping with high impact resistance and positive protection against soil acids. The material is sufficiently perforated to allow troublesome trapped gases and air to escape and thus prevent costly holidays in the coating. Keybestos applies at high speeds with little danger of breakage due to its parallel reinforcement. It is available in widths of 2" - 36" . . . lengths of 50'-2000' . . . and weights of 8 and 15 lbs.

For better, more permanent wrapping of your next pipeline, ask a Midwestern Man to demonstrate the advantages of Keybestos Felt. Contact one of the nine strategically located Midwestern offices shown at the right.

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CORROSION ABSTRACTS

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3. CHARACTERISTIC CORROSION PHENOMENA

3.6 Electrochemical Effects

3.6.2, 6.6.5, 7.2, 3.6.6

Pipe in Concrete Need not Corrode. A. W. Peabody. Ebasco Services, Inc. Consulting Engr., **12**, No. 3, 104-107 (1959) March.

Usual cause of rapid corrosion of steel radiant heating piping installed under concrete is use of a type of construction that creates conditions favorable to formation of strong galvanic corrosion cells (concentration cells) at pipe surface. When pipes are laid directly on a base layer of sand, earth, vermiculite, or other similar material and then covered with poured concrete, small portions of pipe surface are in contact with soil or vermiculite base layer. Voltage between concrete and steel is sufficiently different from that between soil and steel to set up a flow of corrosive current, direction of which is such that steel contacting soil is corroded. Prime requirement for a suitable design is that liquid-carrying steel heating pipes be totally enclosed in concrete slab. Good concrete work is needed; if any of concrete breaks away from pipe surface allowing substantial contact with water, soil or other underlying material, rapid corrosion will result. Methods of pipe support, size of aggregate used in floor slab concrete, circulating medium (use of a completely closed system with as little replenishment of water as possible is recommended), use of cathodic protection where possible to protect poorly-installed systems and question of heating to drive out moisture are discussed. Diagrams.—INCO. 18527

3.6.3, 3.8.4, 6.3.20

Electrical Resistance of Oxide Film on Zirconium in Relation to Corrosion. R. D. Misch and F. H. Gunzel, Jr. Argonne National Lab. J. Electrochem. Soc., **106**, No. 1, 15-19 (1959).

Conductivity of anodic and corrosion films on zirconium was found to increase during heating in vacuum, due to the diffusion of anion vacancies into the oxide with an estimated diffusion coefficient of 4×10^{-13} cm^2 sec^{-1}. Corrosion films produced in water at 350 C appeared to have higher diffusion coefficients. Among the materials zirconium, Zircaloy-1, and Zircaloy-2, specimens of zirconium had the highest corrosion rates and diffusivities. Enhanced oxide growth was observed after corroded specimens were heated at 600 C for 1 minute. The increase in weight gain was greater than would be expected from a simple restoration of dissolved oxide. —EL. 18447

3.6.2, 6.3.20, 4.6.2

Crevice Corrosion of Zircaloy. Alan B. Riedinger. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-ABR-5, August 12, 1958, 25 pp. Available from Office of Technical Services, Washington, D. C.

Zircaloy-3 crevice specimens with varying amounts of retained nitric and

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CO—Centre d'Information du Cobalt, 35 Rue des Colonies, Brussels 1, Belgium.

EL—Electroplating and Metal Finishing, 85 Udney Park Road, Teddington, Middlesex, England.

GRR—U. S. Government Research Reports, Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

HB—Translations, Henry Brutcher, P. O. Box 157, Altadena, California.

IIM—Transactions of The Indian Institute of Metals, 31 Chowringhee Rd., Calcutta 16, India.

INCO—The International Nickel Co., Inc., 67 Wall Street, New York 5, New York.

JSPS—Japan Society for the Promotion of Science, Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1 Chome Nakameguro, Meguro-Ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, 17 Belgrave Square, London SW 1, England.

NALCO—National Aluminate Corp., 6216 West 66th Place, Chicago 38, Illinois.

NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tennessee.

OTS—Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

PDA—Prevention of Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

PI—Pergamon Institute, 1404 New York Ave., N. W., Washington 5, D. C.; Oxford and London, England.

PMR—Platinum Metals Review, Johnson, Matthey and Co., Ltd., 73-83 Hatton Garden, London, E.C. 1, England.

RIM—International Union of Testing and Research Laboratories for Materials and Structures, RILEM Bulletin, 12, Rue Brancion, Paris XV, France.

RML—Review of Metal Literature, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Assoc. of British Paint, Colour and Varnish Manufacturers, Paint Research Station, Waldegrave Rd., Teddington, Middlesex, England.

SE—Stahl und Eisen, Verlag Stahleisen, m.b.H., Breite Strasse 27 (Schliessfach 2590), Dusseldorf, Germany.

TIME—Transactions of The Institute of Marine Engineers, The Memorial Bldg., 76 Mark Lane, London EC 3, England.

TT—Technical Translations, Office of Technical Services, U. S. Department of Commerce, Washington 25, D.C.

ZDA—ZDA Abstracts, Zinc Development Association, 34 Berkeley Square, London W 1, England.

hydrofluoric acids have been corrosion-tested in 750 F steam for 28 days, 680 F water for 112 days and 550 F water for 168 days. These tests show that after an initial period of abnormally rapid corrosion, the corrosion rate becomes normal. The 550 F water test is continuing for a total of 364 days to obtain further confirmatory results. (auth)—NSA. 17569

3.6.5, 3.8.2

Strain Electrometry and Corrosion. Pt. IV. Film Properties and Strain Potential. J. Calvin Giddings, Albert G. Funk, Carl J. Christensen and Henry Eyring. Univ. of Utah. J. Electrochem. Soc., **106,** No. 2, 91-95 (1959) Feb.

Measurements of the strain transients have been recorded here for several metal electrodes including copper, aluminum, zinc, nickel, silver and iron. The magnitude of the transients as a function of the percentage strain are treated by an extension of previous theoretical results. It is found that the transients depend on the position of an electrode in the emf series and on the protective nature of the film as predicted by the theoretical considerations. In addition, several experiments have been reported concerning the effect of corrosion inhibitors and organic coatings on strain transients. Some possible theoretical interpretations are made on these preliminary results. 17677

3.6.5, 6.3.11, 2.3.5

Electrode Potentials and Compound Formation in the Palladium-Platinum-Hydrogen System. A. W. Carson, T. B. Flanagan and F. A. Lewis. Nature, **183,** No. 4653, 39-40 (1959).

Electrode potentials and electrical resistances of palladium wires alloyed with 5-25 percent platinum were measured while they absorbed hydrogen from aq.2N-sulfuric acid. Cf., Lewis et al., Proc. Roy. Soc., 1953, (A) **220,** 279. A two-phase region is indicated in alloys containing less than 25 percent platinum. —MA. 18335

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3.6.5, 4.7

Electro-motive Force Series of Metals in Fused Salts and Activities of Metal Chlorides in 1:1 Molar KCl-NaCl Solutions. S. N. Fengas and T. R. Ingraham. J. Electrochem. Soc., **106,** No. 8, 714-721 (1959) Aug.

Potentials of a series of metal-metal chloride systems in an equimolar mixture of molten potassium chloride and sodium chloride were measured against a silver-silver chloride reference electrode. An e.m.f. series of metals at different temperatures has been established for this particular solvent.—ZDA. 18300

3.6.5, 3.8.2, 6.3.15, 3.4.8

Electrode-Potential Behaviour of Titanium in Fluoride Media. E. M. Khairy and M. M. El-Khatib. Egypt J. Chem., **1,** No. 1, 65-74 (1958). (In English.)

Static electrode potential of titanium was determined at 25 C in buffered solution stirred with nitrogen in the range pH 2-12 with various concentrations of potassium fluoride. E_H/pH plots at pH 4.1, 7.10 and 11.70 showed a sharp break at pH ~1. The measurements indicate that F^- exerts a specific activating effect on the metal surface which depends both on its concentration and the pH. Two types of attack are distinguished; in the first F^- ions penetrate the protective oxide layer with consequent dissolusion of titanium as Ti^{3+}. The dioxide may react under certain conditions to form the TiF_6^{2-} ion. Both mechanisms lead to the depolarization of oxygen adhering to the electrode surface.—MA. 18145

3.6.5, 3.8.2, 3.5.9, 6.3.15, 3.8.3

Effect of Temperature on the Electrode-Potential Behavior of Titanium and Its Bearing on the Mode of Oxidation of the Metal. (In English.) E. M. Khairy and M. M. El-Khatib. Egypt J. Chem., **1,** No. 1, 57-63 (1958).

E'$_o$/temperature plots for solid or plated electrodes in air pass through a minimum and a maximum in the range 25-60 C. Electrodes subjected alternately to hydrogen reduction and to high vacuum gave linear plots. It is assumed that in air titanium is oxidized, forming a thin layer of titanium dioxide on which atmospheric oxygen persists as charged doublets, rendering the electrode surface passive. The difference in potential between the minimum and maximum amounts to 38 mV, corresponding to the discharge of one mole of oxygen via two OH^- ions.—MA. 18144

3.6.6, 6.4.2, 4.2.5, 3.7.3

Mixed Joints of Aluminum and Other Metallic Materials. (In Italian.) Alluminio, **27,** 567-574 (1958) Dec.

Galvanic couples; metals that can be used in direct contact with aluminum and aluminum alloys in saline atmosphere without danger of corrosion; methods of preventing or diminishing contact corrosion; insulating materials; design of insulated joints. 7 references. —RML. 18164

3.6.6, 6.4.2, 6.4.4, 3.7.2, 4.2.5

Galvanic Relationships Between Aluminum Alloys and Magnesium Alloys. Pt. I. Galvanic Couples. M. R. Bothwell. Dow Metal Products Co. J. Electrochem. Soc., **106,** 1014-1018 (1959) Dec.

High-purity aluminum has nearly perfect galvanic compatibility with magnesium AZ31B alloy during saline exposure. This compatibility is little changed by additions to the aluminum of magnesium, silicon or manganese, but it is rapidly and proportionately decreased by the addition of iron, copper and nickel and more gradually decreased by the addition of zinc. The addition of magnesium to the alloy or magnesium ion to the environment can greatly suppress the effect of the above deleterious constituents. 18217

3.8 Miscellaneous Principles

3.8.2, 3.6.5

Potential-pH Diagram for Corrosion. (In Japanese.) T. Okamoto and S. Nagayama. Metals, **28,** 665-673 (1958) Sept.

Corrosion of metal is considered to be an electrochemical reaction (i.e., oxidation and reduction by means of electron transfer). The reaction rate depends on concentration, pressure and especially on electric potential. If equilibrium potential lies between the potential of hydrogen and of metal the reaction can occur, otherwise cannot. The change of Gibbs free energy is related with chemical potentials of the constituent elements and equilibrium potential of the reaction. From this equation, one can get a diagram of the potential versus pH.—MR. 17542

3.8.3

Significance of the Flade Potential. M. J. Pryor. Olin Mathieson Chemical Corp. J. Electrochem. Soc., **106,** 557-562 (1959) July.

Previous explanations of the Flade potential have been reviewed critically. A new explanation based on a single phase passive film of γ — ferric oxide having non-uniform defect concentration and type is advanced. The potential determining reaction is considered to be that between excess oxygen in the outer p-type layers and hydrogen ions and electrons. The inner n-type oxide is destroyed by reductive dissolution in acid media and by exchange of oxygen ions with hydroxyl ions in solution having pH values higher than 3.0. 18522

3.8.3, 6.2.1

Passivation of Iron and Steel in Chromate Solutions. A. H. Kingsbury. J. Australian Inst. Metals, **4,** 12-18 (1959) May.

It is suggested that both chromate ion adsorption and oxide film formation take part in the passivation process. A layer of chromate ions is first adsorbed onto the surface. This adsorbed layer obstructs the electrode processes involved in corrosion and acts as a reservoir of oxidants in intimate contact with the surface and as a shield against ions which could interfere with the orderly growth of an oxide film beneath it. Oxidation by chromate ions (and oxygen in aerated solution) then proceeds under the adsorbed layer. 27 references. —RML. 18477

3.8.4, 6.3.5, 2.3.9, 3.7.4, 3.5.9

A High-Temperature X-ray Investigation of Niobium Pentoxide and Some Problems Concerning the Oxidation of Niobium. H. J. Goldschmidt. B.S.A. Group Research Center, Birmingham,

Eng. J. Inst. Metals, **87**, 235-239 (1959) Mar.

Phase transformations of niobium pentoxide have been investigated by means of high-temperature X-ray photography up to 1230 C, and it is shown that the so-called "high-temperature" (β) allotrope is the truly stable form at all solid temperatures studied, while the "low-temperature" (α) form is metastable and in time always transforms to β. The varying rates for this process have been determined. The nominal transformation point of 900 C has significance only at comparatively high rates of heating. The total oxidation of initially pure niobium metal is followed in sequence, the isothermal stages extending from solid solution of oxygen in niobium to niobium pentoxide. Preferred orientation can be produced in thin films of α-niobium pentoxide as distinct from the random loose oxide. The α or β form of niobium pentoxide can be stabilized by addition of certain oxides of other metals. Silica is an α stabilizer, and in the niobium pentoxide-silicon dioxide system vitreous silicon dioxide coexists with niobium pentoxide; the development of a coherent amorphous layer of this type is considered to be useful from the point of view of protection against oxidation and can be promoted by boride additions. (auth)—NSA. 18293

3.8.4, 6.3.6

Oxidation Kinetics in the Case of Ageing Oxide Films. J. L. Meijering and M. L. Verheijke. Acta Metallurgica, **7**, No. 5, 331-338 (1959) May.

Cubic relationship found by Hauffe and Kofstad for the oxidation of cuprous oxide in the 800-1000 C range is confirmed and also the abnormally low temperature co-efficient of the rate constant. Special experiments show that ageing effect in the cupric oxide layer must be responsible for this behavior. Calculations of the oxidation kinetics are given for the case when the permeability (or its reciprocal) of the oxide formed changes exponentially with age. 20 references.—INCO. 18429

4. CORROSIVE ENVIRONMENTS

4.6 Water and Steam

4.6.2, 3.4.6, 5.7.1, 7.6.4, 7.4.1

Oxygen and Carbon Dioxide Corrosion. P. Brindisi. Celco Labs. Combustion, **30**, No. 10, 47-52 (1959) April.

Well stated summation of water problems encountered in boiler, steam and returns system. Sources of carbon dioxide and oxygen; mechanisms of corrosion; effects and forms of corrosion; and occurrences of carbon dioxide and oxygen in receiving tanks, closed heaters, heat exchangers, boilers and boiler tubes, steam lines and condensate lines are discussed. Prevention of corrosion with good deaeration practices, and by water treatment (caustic soda, zinc rods, chromates, sodium sulfite, hydrazine, amines and acidification) is described. —INCO. 18208

4.6.2, 5.8.2, 8.2.2

Filming Amine Solves Tough Corrosion Problem for Make-Up System. M. E. Osmond and B. Q. Welder. Hagen Chemicals & Controls. Power Eng., **63**, No. 3, 75-76 (1959) Mar.

Monongahela River water is used for make-up for power station at National Tube Works, McKeesport, Pa. Raw water fluctuates widely from hour to hour. Dissolved solids vary 400-1000 ppm, suspended solids 25-1500 hardness 75-350 ppm and pH 3.5-6.5. Water treatment is described. Corrosion in desuperheating condensate system developed after several years of operation. Low-pressure shells were badly corroded, and fittings in spill-over system and piping from condensate storage became extremely serious. Development of filming amines offered solution. Hagafilm treatment reduced corrosion rate of steel panels in desuperheating condensate system from 1285 mg/dm²/day to less than 1 mg/dm²/day with 4-ppm feed and 5-10 mg/dm²/day with 2-ppm feed. Diagram of steam and condensate systems. —INCO. 18541

4.6.2, 5.8.4, 5.7.7, 4.3.2

Cyclohexylamine for Corrosion Prevention in Steam-Raising Equipment. W. K. Ashcroft and P. N. Heron. Corrosion Technology, **6**, No. 3, 85-88 (1959) March.

Describes properties and use of cyclohexylamine in treatment of boiler water to prevent corrosion of metal surfaces by dissolved carbon dioxide. Brief review is made of the mechanism of corrosion and effect of pH. Cyclohexylamine combines with carbon dioxide to form amine bicarbonate, rendering the carbon dioxide non-corrosive to metals. Practical considerations discussed include dosage and adjustment of pH, loss of cyclohexylamine from system, stability of cyclohexylamine and analytical methods for its determination.—INCO. 17768

4.6.2, 6.3.20, 3.7.2

Corrosion of Zirconium Alloys in 900 F Steam. J. Paul Pemsler. Nuclear Metals. U. S. Atomic Energy Commission Pubn., NMI-1208, August 18, 1958, 24 pp. Available from Office of Technical Services, Washington, D. C.

Steam at 900 F is a very corrosive medium for zirconium alloys. Zircaloy-2 and Zircaloy-3 have poor resistance at this temperature. The presence of tin is highly detrimental to the corrosion resistance of zirconium alloys. Additions of nickel, chromium and to a lesser extent iron extend the life of zirconium-base alloys to as long as sixty days before spalling commences. Quenching from the beta phase impairs the corrosion resistance of nickel and chromium alloys and extends the life of iron alloys and the zircaloys. In general, a pretreatment of 10 days in 680 F water has no effect on the corrosion resistance of the alloys tested. (auth)—NSA. 17539

4.7 Molten Metals and Fused Compounds

4.7, 6.3.10, 6.3.6, 6.2.2, 6.2.5

Effects of Fused Alkalis of Lithium, Sodium and Potassium on Nickel, Copper, Iron and Stainless Steel. (In Russian.) E. I. Gurovich. J. Applied Chem., USSR (Zhur. Priklad. Khim.) **32**, 817-822 (1959) Apr. English Translation of Journal Available from: Consultants Bureau, Inc., 227 West 17th St., New York 11, N. Y.

Tests were made of corrosion of nickel, copper, "Armco" iron and stainless steel X18H9T by fused sodium hydroxide at 350, 400 and 450 C, by potassium hydroxide at 400, 450 and 500 C and by lithium hydroxide at 500, 550 and 600 C. Corrosion isotherms and polytherms were plotted and the results

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show that the corrosive attack can be expressed as potassium >sodium >lithium.—NSA. 18292

4.7

Investigation of Phenomena Related to Liquid Metal Corrosion. Period Covered: October 1, 1957 to July 1, 1958. David A. Stevenson and John Wulff. Massachusetts Inst. of Technology. U. S. Atomic Energy Commission Pubn., NYO-2160, August 5, 1958, 13 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

Solubilities of nickel in silver, cobalt in lead, chromium in tin and iron in lead were determined. Data on the rate of solution of copper in lead and nickel in lead at different temperatures were also obtained. (auth).—NSA. 18042

4.7, 3.7.2, 6.2.2

Attack of Molybdenum-Bearing Iron by Molten Zinc Saturated with Iron. (In German.) Dietrich Horstmann. Arch. Eisenhüttenw., **29,** No. 8, 463-466 (1958) August.

Technique described previously (Stahl u. Eisen, **73,** 659, 1953) was employed to study the effect of molybdenum on the resistance of steel to attack by molten zinc. Small molybdenum contents accentuate the attack, but as the content increases the rate of attack decreases, and at 5 percent molybdenum it is less than for mild steel. The temperature range around 500 C, in which the attack follows a linear equation and is very rapid, is extended by small molybdenum additions and constricted by larger ones. The controlling factor is diffusion through the I phase.—MA. 18194

4.7, 3.2.2, 3.7.3

Embrittlement of Solid Metals in a Liquid Metal. W. A. Morgan. Metal Treatment and Drop Forging, **26,** No. 168, 333-339 (1959) Sept.

Review of published work on embrittlement of solid metals by lower-melting point liquid metals with discussion of some theories for this type of failure. Penetration by molten solders, brazing solders, mercury, zinc, tin, lead, brass, copper, cadmium, silver, nickel, white bearing metal, bismuth, sodium, gallium, potassium and lithium is covered. Solid metals considered include nickel, nickel alloys and stainless steels, among others. 57 references.—INCO. 18444

4.7, 3.5.8, 7.3

Metallurgical Examination of a Failed Electromagnetic Liquid Metal Pump Channel. G. H. Broomfield. United Kingdom Atomic Energy Authority, AERE-M/M-228, March, 1959, 10 pp. Available from: United Kingdom Atomic Energy Authority, Research Group, Atomic Energy Research Establishment, Harwell, Berks, England.

A pump channel, which failed by cracking after approximately 950 hrs. service in an isothermal loop containing lead-bismuth eutectic, was examined by metallography, radiography and analysis for causes of failure. No metallurgical defects were found in the tube, but there was evidence of corrosion by the liquid metal. It is concluded that the tube failed in fatigue, probably accelerated by liquid metal corrosion. (auth) —NSA. 18247

4.7, 8.4.5

Screening of Liquid Metal Fuel Reactor Materials and Additives. A. L. Lowe, Jr. and E. J. Rozic, Jr. Babcock and Wilcox. Nuclear Sci. and Eng., **2,** No. 1, Suppl., 24-25 (1959) June.

Because the liquid-bismuth system is susceptible to mass transfer, it was decided that the tilting capsule type of test would be best for a qualitative evaluation of the many variables to be studied. The tilting capsule used for these tests consisted of a 15-in. long, ¾-in. O.D., 2¼ chromium-1 molybdenum steel pipe capped at both ends. Test specimens of molybdenum-titanium, tantalum and beryllium were fastened at each end. The capsule was partially filled with the uranium-bismuth solution containing the desired amounts of additives, zirconium and magnesium. A Δ T of 225 F was maintained between the ends. The necessity of zirconium in the fuel solution as a corrosion inhibitor was verified. The effects of heat treatment and surface preparation on corrosion were studied.—NSA. 18405

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1

Field of Application of Electrical Corrosion Protection by Means of D. C. Equipment. O. Bess. Siemens Rev.,**26,** No. 2, 48-50 (1959) March.

Principles of protection against electrical corrosion and equipment employed, including rectifier equipment, graphite anodes, measuring apparatus and other accessories; table of direct currents and power requirements of protection equipment for various applications.—BL. 18213

5.2.1, 8.9.3

Internal Cathodic Protection. Pt. 3. The Application of Cathodic Protection to the Inner Walls of a Long Pipeline of Circular Cross-Section. C. Plumpton and C. Wilson. Corrosion Prevention & Control, **6,** 53-58 (1959) May. 18509

5.2.1, 2.1.1, 3.8.2

Internal Cathodic Protection. Pt. 2. Application of Cathodic Protection to the Inner Walls of a Rectangular Box. C. Plumpton and C. Wilson. Corrosion Prevention & Control, **6,** 49-54 (1959) March.

Theoretical mathematical analysis of current flow of the anodes.—RML. 18508

5.2.1, 2.1.1, 3.8.2

Internal Cathodic Protection. Pt. I. C. Plumpton and C. Wilson. Corrosion Prevention & Control, **6,** 31-36 (1959) Jan.

Techniques and mathematical principles involved in analysis of cathodic protection problems. General theorems concerning electric current density of re-entrant edges of structures. Examples illustrate determination of potential due to distribution of electrodes in presence of plane boundaries.—RML. 18507

5.2.1, 3.8.2

Theory and Principles of Cathodic Protection by Applied Current and by Sacrificial Anodes. (In German with English Summary). H. Kaesche. Werkstoffe u. Korrosion, **10,** No. 4, 227-239 (1959) April.

Author discusses the current voltage curves of both homogeneous and heterogeneous corroded metals in terms of the superposition of partial current-voltage curves and the phenomenon that the corrosion rate of a metal is reduced if its corrosion potential is displaced in the direction of the equilibrium potential of metal dissolution and deposition. It is known that the corrosion of base metals is increased by traces of noble metals, consequently traces of heavy metals must be inactivated by suitable additives. Aluminum and cadmium are used in the case of zinc anodes and are said to give results that are entirely satisfactory, whereas with pure zinc the iron content may not exceed 0.002 percent. Methods of measuring the degree of corrosion are discussed and finally, the possibilities of corrosion prevention by anodic protection.—ZDA. 18473

5.2.1, 8.9.3

Grounding and Cathodic Protection of Pipe Type Feeders. F. E. Kulman. Trans. Am. Inst. Electrical Engrs., **78,** Pt. 3 (Power Apparatus & Systems), No. 42, 184-190, disc., 190-192 (1959) June.

Discussion of cathodic protection methods now in use which appear to meet two fold requirements of grounding and corrosion protection; results suggest that new and better methods of cathodic protection may be conceived; outline of basic requirements for such methods.—BL. 18381

5.2.2

Cathodic Protection Applications Using Platinum Anodes. H. S. Preiser. Platinum Met. Rev., **3,** 38-43 (1959) April.

Platinum-clad tantalum and titanium anodes for cathodic protection of pipelines, submerged structures, ships, and dock structures are discussed. The disc and plug type anodes are described and the chemical properties of the metals are discussed. 15 references. 18489

5.2.3, 5.2.4

Design of Impressed Current System Cathodic Protection Installations for Painted Steel Plates. (In Japanese.) K. Hoshino. Corrosion Engineering (Japan), **8,** No. 3, 103-105 (1959) March.

When cathodic protection installations for underground or underwater structures are provided, the protecting potential should be as small as allowable and its distribution as uniform as possible, in order to avoid: (1) interference with neighboring structures, (2) hydrogen embrittlement of steel, and (3) deterioration of paint film. Calculation of potential distribution and anode resistance for the fundamental design of those installations was studied, and typical example given.—JSPS. 18459

5.3 Metallic Coatings

5.3.2, 2.3.7, 5.9.3

On the Adhesiveness of Sprayed Metal Coatings. (In Japanese.) Yoshio Harada and Jiro Mizokawa. J. Metal Finishing Soc., Japan, **10,** No. 4, 22-26 (1959) April.

In measuring the adhesiveness of sprayed metal coatings to steel we improved the ASTM jig used for measuring the adhesiveness of rubber sheets to metals. We could obtain so far the reasonable data by means of measuring tensile strength of sprayed coatings adhered to the jig with Araldite.

On zinc coatings, for instance, the sprayed coating by powder spraying method showed far superiod adhesiveness to the ones sprayed by arc and flame spraying methods.

It was found that steel grit blasting was the best pre-treatment method, and sand blasing and emery blasting were inferior to the former. But if the grit

blasting was incomplete, the coating showed rather lower adhesiveness.

Aluminum, brass, copper, etc. showed comparatively good adhesiveness, from the viewpoint of which they were superior to soft metals such as lead and tin.

Molybdenum coatings, when used for an undercoat of ferrous sprayed coatings, took and excellent effect as a bonding coat. Being able to increase the adhesiveness of ferrous coatings at least 1.5 to 2.0 time as much, this treatment is the most suitable for pre-treating a repair part requiring firm adhesiveness.

5.3.2, 7.7

Alumoweld Wire a New Aluminum Coated Steel Wire wit ha Thick Coating. Leslie C. Whitney. Wire and Wire Products, **33,** No. 11, 1362-1364, 1413 (1958) Nov.

In this process for placing a thick coating of aluminum on a steel wire core, the steel rod is fed from a flipper through a straightener and into a cleaner. The aluminum powder is applied to the rod and the composite rod is subjected to heat and pressure to form a solid aluminum coating on the steel core. This wire has a d-c electrical conductance of 33% or, one third that of a solid aluminum wire of the same diameter. Atmospheric corrosion tests of one year, under industrial, marine and rural conditions, have shown that Alumoweld and aluminum wire samples exhibit practically no effects. Further accelerated tests have shown that the corrosion resistance of Alumoweld wires is equivalent to that of EC grade solid aluminum wires. Alumoweld is considered ideal for electrical transmission and distribution lines. When combined with solid aluminum wires in compoiste strands, a wide range of strength and conductance characteristics is possible.—ALL. 17667

5.3.2, 4.6.11, 4.2.5

Corrosion Resistance in Marine Atmosphere of Metal Specimens and Parts Protected with Metallized Zinc Coating. (In French.) J. Cauchetier. Corrosion et Anticorrosion, **7,** 261-264 (1959) June.

Metallized zinc provides excellent protection for parts and structures continually above or below water. Supplementary measures of various kinds are needed for surfaces subjected to alternating action of salt water and air.—RML. 18283

5.3.4

Electrophoretic Coating. D. J. Fishlock. Metal Ind., **93,** No. 26, 537-538 (1958).

High-voltage electrophoresis from aqueous solution was redeveloped to coat a number of materials, such as graphite, ceramics, molybdenum, aluminum and stainless steel to improve their resistance to corrosion, erosion and high-temperature oxidation.—MA. 18142

5.3.4, 6.3.17

Zirconium Coating of Uranium by the Iodide Process. W. L. Robb. Knolls Atomic Power Lab. J. Electrochem. Soc., **106,** 126-129 (1959) Feb.

A method for coating uranium metal with a bonded layer of crystalline zirconium metal has been developed. It consists of thermally decomposing zirconium iodide vapors on the surface of uranium metal heated to about 1100 C in vacuum. Prior to coating, the uranium metal surface is cleaned by iodizing it and then vaporizing the uranium iodide. Greatly increased diffusion between the uranium and deposited zirconium can be obtained if the uranium is alloyed previously with as little as 0.5% zirconium. This increased diffusion improves the corrosion resistance of the coatings. (auth).—NSA. 17812

5.3.4

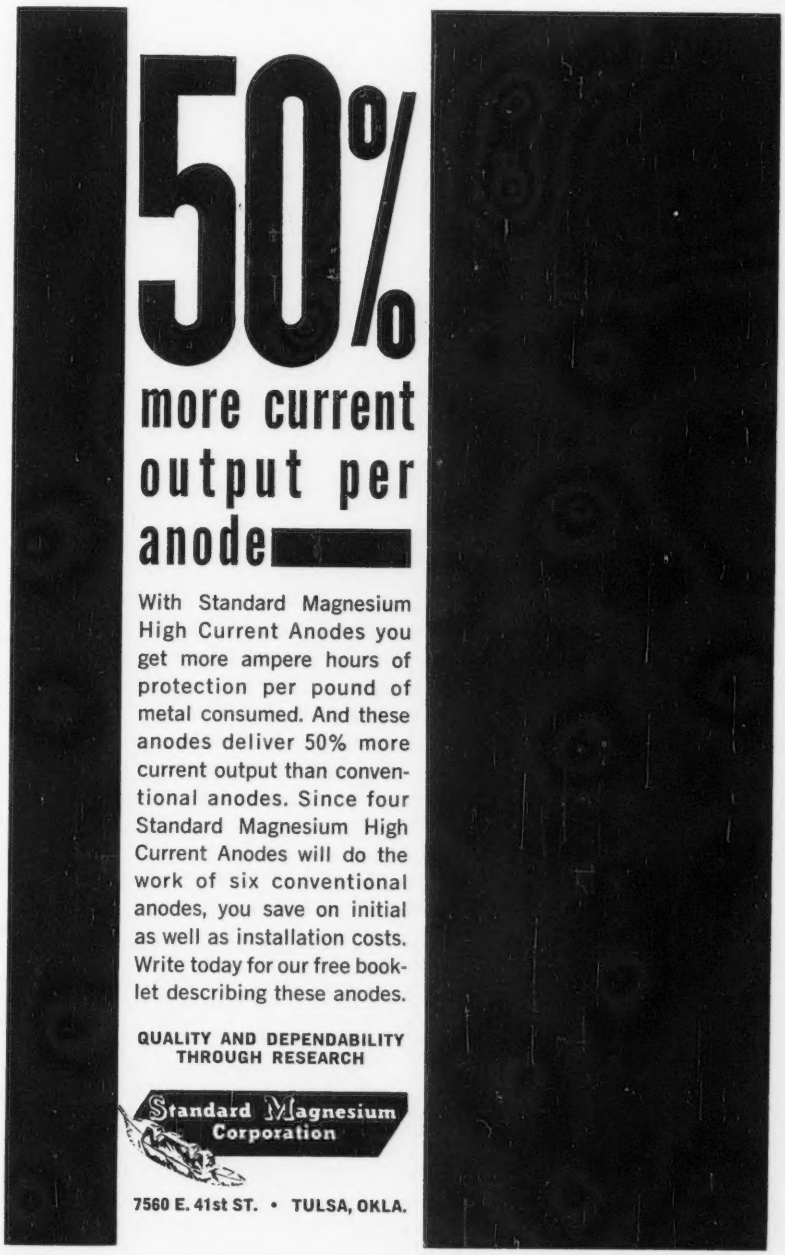
Properties of Nickel Electrodeposited from a Sulphamate Bath. D. A. Fanner and R. A. F. Hammond. Trans. Inst. Metal Finishing, **36,** Pt. 2, 32-42 (1958/59) Winter.

Effects of plating variables, acidity, current density and temperature, on internal stress, microstructure and hardness of nickel electrodeposited from sulphamate bath were determined. Plating conditions for producing minimum internal stress were established and these were used for plating fatigue specimens of En 25 (nickel-chromium-molybdenum) steel and for electroforming nickel sheets for tensile, bend and ductility tests. Effect of addition of wetting agent on pitting and mechanical properties of deposit was investigated. Properties of deposit from Watts type solution were evaluated for comparison. Graphs, tables, photomicrographs.—INCO. 18070

5.3.4

Factors Which Influence the Structure of Electrodeposits. A. M. Max. Tech. Proc. Amer. Electroplaters' Soc., **45,** 73-80; disc., 163-164 (1958).

Mechanism of metal deposition from vapors and electrolytes is discussed. Deposit structure is discussed with reference to current density, temperatures and addition agents. Stress in electrodeposits is related to dislocation theory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and the diffusion of dislocations is used to explain corrosion by the penetration of oxygen or OH^-. 15 references.—MA. 18126

5.3.4, 3.2.2, 5.9.4, 8.8.5

Improved Electroplated Finishes for Zinc Die Castings. W. H. Safranek and C. L. Faust. Plating, **45,** No. 10, 1027-1037 (1958) October.

This paper gives a detailed account of progress on two phases of research for the American Zinc Institute, the study of electropolishing/electroplating procedures for cost reduction in finishing die castings, and the study of plating procedures for improving the corrosion resistance of plated die castings. Data are given for a proprietary electropolishing procedure employing an alkaline solution, said to be the best. Results of tests performed on levelling materials indicate that zinc is superior to nickel or copper. Corrosion research showed that pits or cracks in the chromium plate were accompanied by large numbers of surface pits, partly penetrating the nickel. After complete penetration and perforation of the copper, the zinc alloy corroded rapidly with blistering. To improve corrosion resistance, improvement in chromium plating appeared to be the best procedure, according to the Corrodekote and 192-hr acetic-acid-salt-spray tests.—ZDA. 18155

5.3.4

Possibilities of Chemical Nickel Plating. J. L. Fiedler and J. J. Vanroyen. Rev. Nickel, **24,** No. 3, 53-63 (1958).

Early work and the Brenner, Kanigen, Niphos and hydrazine processes are reviewed. The properties, adhesion and hardness of the deposits are considered, the limitations in cost and in temperature-resistance and absence of catalyst poisons in the parts are treated, and an illustrated survey of the industrial uses of the processes, their hardness and wear resistance and weldability is added. 19 references.—MA. 18156

5.3.4, 6.3.9

Titanium Coatings on Molybdenum Wire. Robert L. Bronnes. J. Electrochem. Soc., **106,** No. 3, 272-273 (1959).

A method is described for the vapor-deposition of titanium on to molybdenum wire. The deposits are firmly adherent and sufficiently ductile to withstand moderate bending.—MA. 18214

5.3.4, 6.3.9, 3.5.9

Use of Nickel-Aluminum Alloy Coatings for the Protection of Molybdenum from Oxidation. W. Beck. J. Electrochem. Soc., **106,** 783-786 (1959) Sept.

Coatings produced by electrodeposition of aluminum on nickel-plated molybdenum protect this metal effectively against high-temperature oxidation. Information about composition and distribution of the nickel-aluminum phases formed in the coatings was obtained from a metallographic analysis of a layer created by deposition of aluminum from the cryolite bath on a sheet of high-purity nickel. 18207

5.3.4

Comparative Investigation of the Corrosion Resistant Action of Zinc, Cadmium and Tin Coatings on Steel. (In German with English Summary.) H. W. Dettner. Werkstoffe u. Korrosion, **10,** No. 5, 321-326 (1959) May.

Galvanized coatings of 2μ, 5μ and 10μ were tested for corrosion resistance. Chromated and non-chromated coatings of zinc were applied in matte or various commercial cyanide gloss baths. Cadmium coatings were non-chromated. Tin was applied as a hot dip coating or electroplated from acid or alkaline baths. The hot dip coatings were applied with and without an intermediate layer of copper or nickel. A nickel intermediate layer gave a better result with tin than did a copper layer. Passivating improved the corrosion resistance of zinc. According to the salt spray test, cadmium gave better results than zinc. 1 table.—ZDA. 18280

5.3.4, 5.9.2, 6.3.21

Electroplating on Thorium. John G. Beach and Glenn R. Schaer. J. Electrochem. Soc., **106,** No. 5, 392,-393 (1959).

Thorium anodically pickled in 1.2N-hydrochloric acid followed by a chemical pickle in 3.6N-sulfuric acid can be plated with most metals. Factors affecting adherence and corrosion performance are discussed.—MA. 18240

5.3.3

Specifications for Protective Plating. Pt. I. E. A. Ollard. Corrosion Prevention and Control, **6,** No. 3, 36-39 (1959) March.

Summarizes plating specifications for decorative and/or protective nickel or nickel plus chromium plating of number of articles, including car nave plate, die cast car door handle, electric iron, brass ash tray, clock bezel, scientific instrument parts, camera parts and aluminum coffee pots.—INCO. 18540

5.3.4, 5.4.5, 4.6.11, 4.6.7

Combination of Metallizing and Painting for the Protection of Metal Parts. F. Podbreznik. Zastita Materijala, **7,** No. 1, 32-33 (1959) Jan. (In Serbo-Croat.)

This article is a discussion on the protection of metals in sea and fresh water. Danish, English and other findings are quoted. The uses of zinc chromate paints and zinc plating are described and some coating costs are given.—ZDA. 18512

5.3.4

Zinc Silicate Type Coatings. C. L. O'Neill. Australian Corrosion Eng., **3,** No. 5, 12-13 (1959) May.

Merits of a 'Galvanite' coating, which is said to be equivalent to high quality hot dip galvanizing, are stated. The coating is described as essentially metallic zinc powder in a sodium silicate vehicle. The pigment and vehicle are mixed just before application, following which the paint may be baked at 400 F or chemically cured. It has been used on 240 mile pipelines in South Australia, where the coating was applied in 1942-43 and is said to be in excellent condition still. It is claimed that it will withstand temperatures up to 700 F and short periods at 1100 F. One coat gives approximately 1 oz of zinc/sq ft of surface area. The cost of application is said to be two-thirds of that for zinc spraying.—ZDA. 18535

5.3.4

Passivated Zinc and Cadmium Deposits on Steel. (In German.) M. J. Reidt. Galvanotech., **2,** No. 2, 198-204 (1959); Metal Finishing Abstracts, **1,** No. 2, 54 (1959) Mar./Apr.

Samples of steel were zinc plated in a bath containing zinc cyanide 72-79 g/1, total sodium cyanide 120-125 g/1, caustic soda 80-88 g/1, Zyntax brightener 6 g/1. Brightening in 0.6 percent nitric acid was followed by passivation in Zonax passivating salts 100 g/1 for 3-10 seconds with agitation at room temperature. For cadmium plating the bath contained cadmium oxide 25 g/1, caustic soda 345 g/1, total sodium cyanide 125 g/1, with Kadamax brightener 9 g/1. 1 percent nitric acid was used for brightening and the samples were passivated as for zinc. Outdoor corrosion test results and coating thickness distribution over the panel are given for different average thicknesses. It is concluded that the corrosion resistance of passivated zinc is, in general, better than that of passivated cadmium deposited on steel. —ZDA. 18517

5.3.4

Molybdenum Plating Inside of Large Bore Tubes. P. L. Raymond. National Research Corp. J. Electrochem. Soc., **106,** No. 5, 444-448 (1959) May.

Technique was developed for production of relatively heavy molybdenum plates inside of tubes by hydrogen reduction of the pentachloride. Most of plating runs were made on tubes of AISA 4620 with 1⅝ in. bore. Various substrates were used as basis for molybdenum plate, in addition to cleaned but otherwise untreated steel. Electroplates of copper and of nickel and chemical plates of nickel and of cobalt were tested. Cobalt chemical coatings gave best results and were used in later stages of development. Best molybdenum deposits were produced when vapor concentration was held constant throughout run. Wide hot zone produced by induction coil proved superior to narrow hot zone produced by external gas burner. It was essential to maintain large excess of hydrogen in vapor stream to insure complete reduction, in order to produce dense deposits. Photomicrographs.—INCO. 18529

5.3.4

Atmospheric Corrosion Resistance and Metal Coatings. J. H. Nicholls. Prod. Finishing, **12,** No. 5, 65-67 (1959) May.

Author describes the properties of a coating, known as AHFO and developed by Electrochemical Processes Ltd., in which tin is deposited on top of a cadmium layer already present on a steel base. Comparisons are made with a galvanized coating. The composite coating is available in three grades, having a total film thickness of 0.0002, 0.0003 and 0.0005 in., the ratio of tin: cadmium thickness lying between 1:10 and 1:5. The process was developed to combat corrosion problems encountered in the printing industry and it is claimed to be particularly resistant in an acidic environment. The humidity and salt spray tests, described in B.S. 1391 are said to have no effect on the coating and the sulfur dioxide test had no perceptible action on the heavier coating after three months. The coating is said to possess exceptional ductility and adhesion and an attractive appearance. It is claimed that it can be burnished, riveted, seamed, soldered and spot welded without difficulty. The method of depositing the tin, which is the subject of a patent application is not described. 3 figures.—ZDA. 18501

5.3.4, 6.2.2

Direct Chloride Tinning Process Has Universal Application. E. S. Hedges. Ind. Finishing, **11,** No. 127, 28-30 (1959).

Previous methods of tinplating cast iron are reviewed and the direct chloride

process, now in commercial use, is described. Shot blasting replaces acid pickling and a flux containing zinc chloride, sodium chloride and ammonium chloride is used to cover the tinning bath. The relative merits of the various methods available for tinning cast iron are discussed.—MA. 18456

5.3.4

Study of Various Pretreatment for Plating on Aluminum. (In Japanese.) Matsuhei Kishi. J. Metal Finishing Soc., Japan, **10,** No. 8, 293-297 (1959) Aug.

A few well known methods of pretreatment for electro-plating on aluminum are studied. The results show:

1. Best adhesive property of electrodeposit is obtained by pretreatment in a nickel chloride bath, however, the plated surface is slightly rough.

2. Electron microscopic observation of the chemically treated surface revealed that the wavy structure is produced by zincate immersion, cleavage like structure by nickel chloride immersion and granular structure by other treatments. The deposit of granular structure is generally less adhesive.

3. The adhesive property does not always depend on the electrode potential. 18478

5.3.4, 8.4.3, 6.2.3, 6.2.4

Aluminizing Resists Refinery Corrosion. C. F. Tisinai and C. H. Samans. Petroleum Refiner, **38,** 153-160 (1959) June.

Aluminizing carbon steel or low-alloy steel is an inexpensive method of protection against refinery sulfidation and oxidation.—RML. 18548

5.4 Non-Metallic Coatings and Paints

5.4.2

Ceramic Coatings for the Control of Radiant Heat. E. A. Douglas. Brush Beryllium Co. Paper before Am. Ceramic Soc., 58th Annual Meeting, New York, April 23, 1956. Am. Ceram. Soc. Bull., **38,** No. 1, 20-23 (1959) January.

Investigation was made of emissivities of ceramic coatings for low alloy steels. It was found that most dark refractories gave highly emissive coatings. Best white refractory materials for use in low emissive coatings at 1200 and 1500 F were feldspar, zirconium spinel, and Treopax. Emissivities of white coatings were dependent on purity of white materials and amount of binder glass used. Steels tested included 3 chromium-1 molybdenum-TiB, 6 chromium-1 molybdenum-TiB, Allegheny CM (14-18 chromium, 13-15 manganese, 1 nickel), and Timken 17-22 (AS). Emissivity data are included for nickel oxide.—INCO. 18277

5.4.2, 6.3.17, 6.3.21, 8.4.5

Development of Ceramic Coatings for Uranium and Thorium. G. L. Ploetz and C. W. Krystyniak. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-1609, Sept. 1956 (Declassified April 6, 1959), 11 pp. Available from Office of Technical Services, Washington, D. C.

Full-size Hanford uranium slugs have been successfully coated with vitreous porcelain enamels with consistently good results. Uranium-1.5 at. percent silicon alloy and uranium-0.5 at. percent chromium alloy disks and slugs were amenable to coating by the same techniques used with unalloyed uranium. Glasses of

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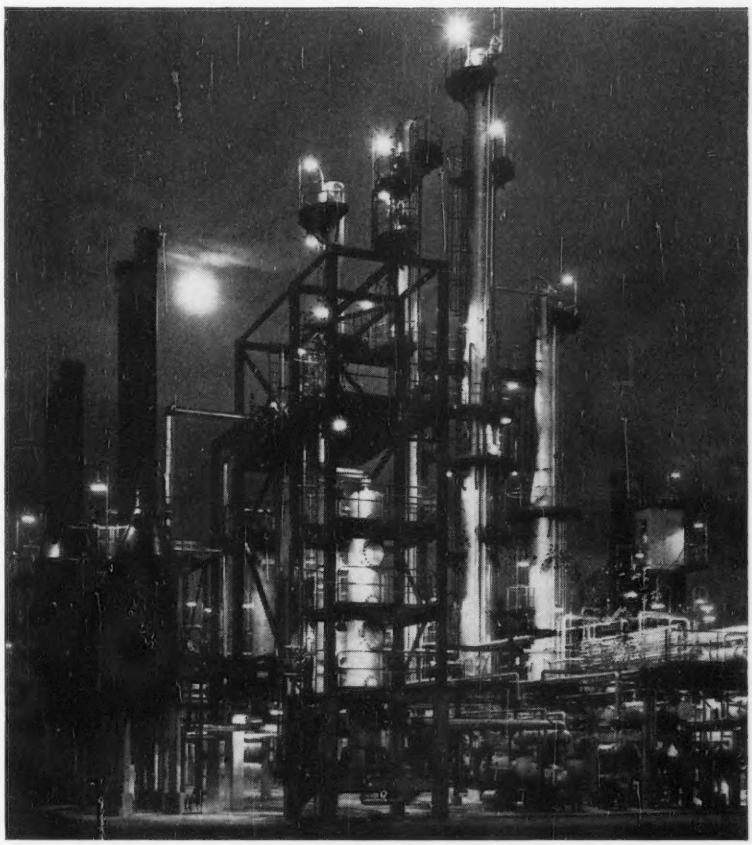

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beryllium fluoride base were developed as low-temperature uranium coatings, but these had poor corrosion resistance and softening temperatures too low for the present application. Thorium metal strips, disks and small slugs were coated with less difficulty than uranium or uranium alloys. Thorium did not oxidize as rapidly during the firing operation and did not require electropolishing as a pretreatment before enameling. (auth) —NSA. 18491

5.4.3, 6.6.7, 6.6.8

How to Protect Metals with Elastomeric Linings. L. A. Woener. Materials in Design Eng., 46 No. 2, 94-98 (1957).

Principal elastomeric lining materials are described-natural rubber and synthetics which include Neoprene, nitrile and butyl rubbers, and Hypalon. Although not an elastomer, polyvinyl chloride is included. Their resistance to a wide range of chemicals at normal and elevated temperatures are discussed and tabulated.—MA. 17938

5.4.5

Synthetic Rubber (Styrene/Butadiene) Latices as Coatings for Metals. (In French.) A. Destable. Peintures, Pigments, Vernis, **35,** No. 2, 72-74 (1959).

A styrene/butadiene copolymer latex for use in coatings for steel surfaces, e.g., in primers for car bodies, is described with particular regard to formulations containing red iron oxide pigment. Some typical formulae are tabulated and discussed. The pH of the paint is preferably adjusted during the last stage of manufacture to either 5-6 or 10-11. At the lower pH, obtained by addition of 10 percent acetic acid, the paint is used without drier; adjustment to the higher pH is carried out with 28 percent ammonium solution and manganese drier (preferable to cobalt or lead) is then employed. Optimum film properties are obtained by brief air-drying followed by stoving at 350 F (177 C) for 20 minutes.—RPI. 18305

5.4.5, 8.8.1, 4.2.4

Chemical Plant Protection by Epoxide Resin Based Coating Systems. J. Rogers. Corrosion Prevention and Control, **5,** No. 6, 53-56, 58-60 (1958) June.

Use of epoxy resin based coatings in chemical plants is considered in the following general locations: (a) direct contact with corrosive liquids, e.g., linings of pipes and containers, (b) exposure to highly corrosive fumes with the chance of occasional spillage, (c) exposure to mildly corrosive fumes and (d) exposure to polluted industrial atmospheres.—RPI. 18030

5.4.5

Protecting Steelwork with Epoxide Enamel. G. A. Dell. Corrosion Technology, **5,** No. 9, 291-292 (1958).

Use is described of an air-drying twin pack material of which the major constituent is an epoxy resin solution pigmented with either titanium dioxide or other pigment according to the color required. The minor ingredient or curing agent is a special blend, principally of polyamide-type resin, which reacts with the epoxy resin after mixing. The mixed paint assumes its best characteristics some 8-16 hr. after mixing, according to the prevailing temperature at the time. If the material is used soon after that period, the resultant dry films will show their best properties.—RPI. 18050

5.4.5, 4.3.2, 4.3.3, 7.6.7

Urethane Coatings for Preventive Maintenance. E. J. Aquadro. Paint Ind. Mag., **74,** No. 2, 17-19 (1959).

A urethane coating based on a isocyanate/castor oil prepolymer extended the life of a wooden filter press subjected to both acid and alkaline solution from 4 months to 2 years. Fans and ductwork carrying highly corrosive vapours were also treated with this urethane coating and are behaving well.—RPI. 18244

5.4.5

Organic Coatings for Metal Products. R. J. Fabian. Materials in Design Eng., **49,** No. 3, 113-128 (1959) March.

Chemical, physical and decorative properties of coatings for metals are considered and compared in tabular form. Application methods are also compared similarly. The individual materials considered for use as coating compositions include alkyd resins, urea and melamine resins, acrylics, cellulosics, coumarone/indene resins, epoxy resins, fluorocarbon resins, phenolics, polyamides, silicones, styrene/butadiene copolymers, polyurethanes and vinyl resins. Particular applications of each of these are given. 17 references.—RPI. 18370

5.4.5

Epoxide Resins Versus Corrosion. L. M. Barakan and G. L. E. Wild. Paint Manufacture, **29,** 9-12 (1959) Jan.

Discussion of finishes based on epoxide resins with special reference to their corrosion preventing properties.—BTR. 18344

5.4.5

Marine Paints and Compositions. T. A. Banfield. Corrosion Prevention & Control, **6,** Nos. 6, 7; 51-55; 38-48 (1959) June, July.

Treatment of structural steel before painting; priming paints; general finishing paints for ships and paints used on ships' bottoms; wood priming paints for yachts.—BL. 18308

5.4.5, 5.9.3

Physico-Chemical Properties of Zinc Dust Paints. (In German.) P. Colomb. Chem. Rundschau (Switzerland), **12,** No. 5, 106-108 (1959).

Zinc dust paints are based on zinc powders with a mean particle size of 5.5μ, or, in the case of super-fine grade, 2.5μ. Conventional binders are listed. Erichsen tests on painted samples show that the adhesion of the paint coating depends on surface preparation, particularly cleaning; maximum adhesion was obtained with sand blasting. The thicker the paint coating, the poorer is its elasticity and adhesion. Corrosion is not prevented by cathodic protection but by the formation of zinc hydroxide as a corrosion product, which gradually fills up pores or cracks in the paint film.—ZDA. 18306

5.4.5, 7.1

Protective Coatings for Missile Printed Circuits. A. E. Hawley and W. E. Weber. Paper before Soc. Plastics Engrs., 15th Annual Tech. Conf. Elec. Mfg., **63,** No. 6, 58-62 (1959) June.

Report provides data on formulation and characteristics of several coatings specially developed for missile printed circuits. Epoxy and silicone types appear to be particularly advantageous. Test procedures for viscosity and pot life, solvent entrapment, insulation resistance and thermal shock are detailed. Insulation resistance measurements were conducted in specially constructed humidity chamber.—INCO. 18458

5.4.5

Coatings Based on Epoxide Resins. J. T. Leonard. Product Finishing, **12,** No. 1, 56-65, 84 (1959).

General properties of epoxy resin esters, epoxy-based alkyds, amine- and polyamide-cured epoxy resins and various combinations of epoxy resins with urea, melamine and phenolic resins are considered and suitable applications for coatings based on the various systems discussed with illustrations.—RPI. 18392

5.4.5, 3.5.5, 6.3.6, 5.4.7

Possibilities and Limitations in the Corrosion Protection of Brass. (In German.) G. Marwedel. Farbe u. Lack, **65,** 64-71 (1959) Feb.

Porosity of organic protective coatings requires a certain layer thickness. Full protection is afforded by baked-on lacquer.—RML. 18414

5.4.5, 1.3

Recent Developments in the Field of Rust-Preventive Paints. (In German.) K. Krenker. Werkstoffe u. Korrosion, **10,** No. 1, 1-14, (1959) January.

This comprehensive survey includes brief references to zinc dust paints, for which a minimum thickness of 200 microns and thorough precleaning are stressed, and zinc pigments, in whose use the formation of zinc soaps must be considered as it may lead to eventual embrittlement of the coating under atmospheric influences. 9 figures.—ZDA. 18393

5.4.5

Plastisols and Organosols. Metal Coatings Supreme. L. D. Maines Plating, **46,** No. 3, 235-238 (1959) March

Respective advantages of plastisols and organosols; their composition and properties; savings made possible with vinyl dispersion coatings; surface metal preparation; dipping and spraying noted as two most popular methods for applying coatings; use of vinyl dispersion coatings by electroplating industry; other examples.—BL. 18406

5.4.8

Modern Organic Finishes with Special Emphasis on Coatings for High Temperature and Abrasion Protection. M. A. Glaser and E. J. Bromstead. Official Digest, Federation Paint, Varnish Production Clubs, **31,** No. 410, 392-409 (1959).

A vehicle guide is given, listing media against a number of desired properties. Some properties, including abrasion resistance, of some newer coatings are also tabulated. Other matters considered are methods of application, heat resistance and electrical properties of silicone coatings, coatings for aircraft and missiles and coatings for magnesium. Water-based coatings set a pattern for the future and inorganic polymers have been reported. Fundamental information of the function of coatings is required.—RPI. 18373

5.4.8, 4.2.1

Protection of Metals by Corrosion-Resistant Paints. (In French.) George Nedey. Nature, No. 3287, 112-116 (1959) March.

Protection of metals exposed to either atmospheric conditions (O_2, H_2O vapor and corrosive industrial gases) or to

acid solutions, alkaline or saline. Efficiency of the protection depends on the adhesion of paint to the metal surface and its impermeability to liquids and gases.—RML. 18532

5.4.10, 7.2

Polyvinyl Chloride Tapes for Pipe Protection. K. S. Chitty. Corrosion Technology, **6,** No. 2, 39-41 (1959) Feb.

Physical and insulating properties of polyvinyl chloride tapes; protection of pipe from corrosive and abrasive conditions.—RML. 18326

5.4.10, 8.9.3

Pipe-Wrapping Materials for Corrosion Protection. J. G. Parry and J. R. James. Corrosion Technology, **6,** No. 2, 35-37 (1959) Feb.

Functions of pipeline coatings. Characteristics of asphalt, coal tar and plastic tape coatings and inner and outer wraps of glass fiber, asbestos or kraft paper. —RML. 18546

5.4.10

Coating Steel Pipe for Gas Service. J. S. Dorsey and C. E. Lee. Southern Calif. Gas Co. Gas, **35,** No. 3, 129-132, 134, 138 (1959) March.

Standard pipe coatings used at Southern California Gas Co. are listed. Asphalt was chosen as a standard because it has given good service and is economical. Plastic tape is used to make field coating joints on straight pipe and smooth bends. Grease is usually used on irregularly shaped fittings. Asphalt paints are also used in conjunction with plastic tape on insulating flanges. Purchase specifications, yard wrapping, stockpiling in yard or in field, installation of pipe, laboratory and field testing of coating materials, field wrapping, field testing of coating just before installation and evaluation of performance of coatings in service are considered. Tables, photos.—INCO. 18309

5.5 Oil and Grease Coating

5.5.2, 5.8.2, 4.2.7, 3.4.9, 6.2.3

Protective Action of Volatile Inhibitors and Anticorrosive Greases at Tropical Temperature and High Humidity. (In Russian.) B. E. Piskorskii and E. M. Il'ina. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **32,** No. 1, 138-141 (1959) Jan. English Translation of Journal available from: Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York.

Strips of low carbon steel were tested for corrosion with or without an anticorrosive grease coating. The following liquid greases were used: vaseline oil with or without the addition of 2 percent of the barium soap of montanone (a synthetic wax prepared from bituminous lignite), 4-10 percent ceresin, or 5-10 percent lanolin; vaseline oil with 2 percent ozocerite and 10 percent potassium chromate in suspension; and a 10 percent solution of aluminum oleate and ozocerite in naphtha. The presence of dicyclohexylammonium nitrite, or urea as inhibitors improved the protective effect of the aluminum oleate-ozocerite coating. 2 tables, 5 references. 18547

5.5.3

Stopping Corrosion with Rust-Preventive Compounds. R. P. Mills. Iron Steel Eng., **34,** 95-98; disc., 98-100 (1957); J. Iron & Steel Inst., **188,** Pt. 3, 315 (1958).

An elementary account of corrosion processes and the petroleum compounds used to prevent them, with notes on testing. Some particular cases were mentioned in the discussion.—RPI. 17992

5.5.3, 5.4.5

Anticorrosive Properties of Epoxidized Oils. H. W. Chatfield. Paint, Oil and Color J., **133,** Nos. 3097, 3098, 3099; 398-399, 446-447, 522, 524 (1958).

The effect of the addition of epoxidized oils on the anticorrosive properties of a wide range of products has been examined. These include clear media possessing no specific anticorrosive properties, which were often imparted by the epoxidized oil, and conventional anticorrosive paints, both air-drying and stoving, where the inclusion of epoxidized oil often enabled the proportion of anticorrosive pigment to be reduced and improved such properties as adhesion and resistance to blistering.—RPI. 17118

5.5.3, 3.4.9, 5.8.1

Corrosion Studies. Pt. XVI. The Effect of the Penetration of Water Vapor Through Oil Films on the Corrosion of Steel Protected by Oil Film. (In German.) R. Bartoníček. Collection Czechoslov. Chem. Communs., **23,** 1174-1180 (1959) July.

Corrosion inhibitors which are not prepared from oil have a very poor protective effect because of their permeability to water vapor. To obtain a more useful protective effect, the permeation velocity of vapor through the preservative prepared from petroleum must be a minimum and inhibitors which decrease the corrosion susceptibility and therefore determine the protective effects of the preservative must be added to the hydrocarbon. The protective effects of these inhibitors are obtained by the formation of a water repelling layer on the steel surface or by its capacity to passivate the metal surface. (auth)—NSA. 18315

5.8 Inhibitors and Passivators

5.8.2, 3.6.8, 4.4.3

Corrosion Inhibitors in Automotive Coolants. Polarization of Solder and Copper. M. Levy. Aberdeen Proving Ground. Ind. & Eng. Chem., **51,** No. 2, 209-210 (1959) Feb.

Presents polarization data for copper and solder (50 lead-50 tin) specimens in 30 percent ethylene glycol and in tap water with following inhibitors: borax, sodium nitrite, sodium citrate, sodium chromate, sodium silicate, triethanolamine, sodium benzoate, hydroquinone, and mercaptobenzothiazole. Data are compared with previous polarization studies with steel. In all experiments solder was anodic to copper and no reversals of polarity were observed. In steel-copper couple, reversals of polarity were recorded in sodium nitrite, triethanolamine, sodium benzoate and sodium silicate-treated solutions. Table, graphs. —INCO. 18385

5.8.3, 6.3.6, 4.3.3

Inhibition by Sugar of Copper Corrosion in Ammonia Solutions. J. A. Radley, J. S. Stanley and G. E. Moss. Corrosion Technology, **6,** No. 8, 229-231 (1959) August.

Very strong inhibiting action observed on copper when small amounts of glucose are added to ammonia solutions is probably due to copper catalyzed reduc-

J. M. PEARSON

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tion of dissolved oxygen. Such a reaction could not occur with zinc or aluminum since these have only one stable valency state in solution and cannot catalyze reduction of dissolved oxygen. Inhibition on copper observed with nonreducing sugars and sugar alcohols such as sorbitol and mannitol, which are incapable of reducing copper to cuprous state and, therefore, of removing dissolved oxygen, is probably caused by fact that they stabilize cupric valency state of copper and thus prevent reaction at metal surface. Tables.—INCO. 18485

5.8.3, 3.8.3

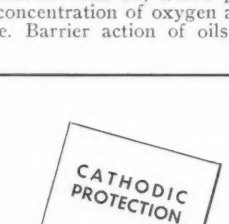
Inhibitors and Passivators and Their Role in Protection. (In German.) Willibald Machu. Arch. Eisenhüttenw., **30,** No. 3, 145-152 (1959) March.

Adsorption and chemisorption of molecules on metal surfaces are discussed and passivation and polarization effects considered. Current concepts of the mechanism of inhibition and passivation are reviewed and their commercial application dealt with.—MA. 18408

5.8.4

How Polar-Type Oils Inhibit Corrosion. R. A. Powers and J. C. Cessna. National Carbon Co. Ind. & Eng. Chem., **51,** No. 7, 891-892 (1959) July.

Polar-type inhibitor oils may decrease corrosion of steel by promoting and maintaining passive surface under conditions where it would not otherwise occur. Passivating agent is dissolved in oxygen rather than oil, which provides higher concentration of oxygen at metal interface. Barrier action of oils permit passivity to be maintained under unfavorable conditions. Experimental results are given. Graphs, 24 references. —INCO. 18503



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5.9.4, 6.4.2, 6.4.4

Protective Anodizing. F. C. Porter. Corrosion Prevention and Control, **6,** No. 3, 40-44 (1959) March.

This is a review article on the anodizing processes for producing a protective coating on aluminum (and magnesium). It covers the aspects of choice of alloy, joining processes, anodizing practice, properties of anodized aluminum, cleaning and maintenance of anodized surfaces, applications and general design requirements.—ALL. 18510

5.9.4, 3.8.3, 6.3.10

Anodic Dissolution and Electrolytic Polishing of Metals. J. K. Higgins. Atomic Energy Res. Establishment, Harwell Berks, England. J. Electrochem. Soc., **106,** No. 12, 999-1005 (1959) Dec.

An experimental study has been made, using the potentiostat technique, of the anodic dissolution and electrolytic polishing of nickel in hydrochloric acid. The effect of experimental conditions on the potential/current density curves and the value of the limiting current density has been investigated. Results have been interpreted on the basis of a simple diffusion mechanism and complications arising from the thick salt films found in the more concentrated solutions have been considered. Some results showing the connection between polishing and passivity have been collected for copper anodes in potassium cyanide solutions containing potassium hydroxide. 18438

5.9.4, 5.4.5

Chemical Surface Treatment of Steel Strip as a Protective Against Corrosion, to Improve the Adhesive Strength of Coatings and to Form Insulating Layers. (In German.) Werner Rausch. Stahl u. Eisen, **79,** No. 6, 349-356 (1959) March 19.

Surface treatment of steel strip to improve the storekeeping ability and the adhesion of varnish and plastic coatings. The application of insulating layers to electric sheets. Phosphate coatings to facilitate the workability of deep drawing steel sheets. Increasing the resistance to corrosion and the adhesion of varnish of galvanizing sheets.—BTR. 18549

5.9.4, 5.8.1, 6.3.19

Potential Studies on Passivity to Corrosion Induced by Pretreatment Processes. Pt. II. Comparative Study of Chromate Treatment and Chromate Inhibition. K. S. Rajagopalan and K. Balakrishnan. Central Electrochemical Research Inst., Karaikudi, South India. J. Electrochem. Soc., **106,** 562-566 (1959) July.

Mechanism of passivation of zinc by chromate treatment is compared with that of chromate inhibitor in this paper. The part played by soluble chromate in enhancing passivation by chromate treatment is elucidated in terms of the kinetic approach made in a previous paper. 18550

5.11 Design-Influence on Corrosion

5.11, 3.2.2, 3.6.2, 3.6.6, 3.5.8

Design for Corrosion Resistance. N. D. Groves. Carpenter Steel Co. Product Eng. (Design Digest Issue), **30,** No. 38, 62-64 (1959) Mid-Sept.

Discusses basic design practice that should be followed to improve resistance to all types of corrosive attack. Corrosion cures are considered for intergranular, concentration cell, galvanic, pitting, stress corrosion cracking, fretting, and erosion types of corrosion. Photographs illustrate each type.—INCO. 18268

5.11, 5.2.1, 8.9.3

Designing for Minimum Cathodic Protection Interference. C. A. Erickson. Peoples Natural Gas Co. Gas, **35,** No. 3, 70-71 (1959) March.

Elimination of cathodic protection interference on other underground structures is one of most aggravating and costly steps in protection of a pipeline against corrosion. Some steps are suggested which, if taken during design stage, will minimize interference and make it easier to clear. By measuring soil resistivities along proposed route, corrosion engineer can locate highly corrosive areas, which should be avoided if possible. Greatest single factor in minimizing interference is a good coating on pipeline. Most companies specify a good coating and minimize imperfections by rigid inspection. Exposed metal at penetrations is then protected with cathodic protection. Types of cathodic protection systems, use of insulating joints, and cost factors are among other topics discussed.—INCO. 17704

5.11, 8.9.3

Plan Protection When Designing System. M. E. Parker. Petroleum Eng., **31,** No. 3, D19-D21 (1959) Mar.

In planning a corrosion control system for a pipeline the economic point is reached when another dollar spent on coating will save less than a dollar on cathodic protection cost. Accessibiity of various parts of the line, insulated joints, and test lead locations must be specified during the planning. 18538

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.1, 6.3.4, 7.1, 3.5.9, 3.7.3

High-Temperature Alloys. Michel Urbain. Cobalt, No. 1, 13-32 (1958) Dec.

Applications of heat-resisting alloys to the construction of aircraft engines, rockets, airframes, missiles and marine and land gas turbines are discussed. The composition of a number of iron-base, iron-chromium-nickel-cerium, nickel-base, and cobalt-base alloys is shown in tabular form, and discussions are included on the effects of composition and structure on high-temperature properties. Significant engineering properties of these alloys were compared. Data are included on the following: tensile tests at room and high temperatures; stresses necessary to cause rupture in 100 and 1,000 hours at various temperatures; high-temperature fatigue resistance; oxidation resistance; and thermal shock resistance. Considerations are given to hot forging and rolling, cold working of sheets and the weldability of superalloys.—NSA. 18053

6.2.2, 3.7.2, 3.2.2

Properties of Pure Iron Charged with Cathodic Hydrogen in the Presence of Sulfur, Arsenic and Antimony. (In French.) Simone Besnard, Christian Messager and Jean Talbot. Compt. rend., **248,** 1516-1519 (1959) March 9.

Experimental results showing the diffusion of some impurities into iron during charging with cathodic hydrogen are presented. Optical micrography and electron microscopic study indicates the existence of an intergranular precipitation which makes the metal brittle. (auth)—NSA. 18222

6.2.2, 3.8.4

Oxidation of Iron-Nickel Alloys. Pt. III. Kinetics of Oxidation of Three Commercial Alloys. R. T. Foley and C. J. Guare. General Electric Co. J. Electrochem. Soc., **106,** 936-940 (1959) Nov.

Three commercial iron-nickel alloys, containing 30, 41 and 78 percent nickel, were oxidized over the range 600-1000 C in two atmospheres, laboratory air, and a 21.7 percent oxygen-78.3 percent nitrogen mixture. The oxidation of these alloys follows a parabolic weight gain-time relationship during the 60-min. reaction time. Replicate experiments generally showed that the precision in determining the parabolic rate constants was better in the oxygen-nitrogen mixture than in laboratory air. This effect is probably the result of day-to-day variations in composition of laboratory air. Temperature dependences of the reaction rates were determined with the Arrhenius-type equation. Both the reaction rates and the apparent energies of activation of the 30-41 percent alloys are consistent with a rate-determining process of cation diffusion through a spinel structure $Ni_x\ Fe_{3-x}\ O_4$. It is hypothesized that the apparent energy of activation for the 78 percent alloy is due to the influence of the 3.8 percent molybdenum on the physical character of the film. Anomalously high rates were observed in both atmospheres at the higher temperatures and this is discussed with reference to "over-temperatures," resulting from heat generated at the surface by oxidation. 18271

6.2.2, 3.2.3, 3.7.2

Scale Resistant Alloys. (In Hungarian.) R. Radtke. Kohaszati Lapok, **14,** 127-131 (1959) May.

Ferritic-base cast alloys in relation to scale formation. The influence of various alloying elements is defined. Silicon is claimed to have a good effect on scale prevention. Protective layers of spinell-structure are recommended.—RML. 18530

6.2.2, 4.6.11

Types of Gray Cast Iron Used for Marine Equipment. (In French.) Roger Poirot. Fonderie, No. 161, 251-261 (1959) June.

Compositions and properties of spheroidal, sorbitic, bainitic, martensitic and austenitic cast irons. Corrosion resistance in sea water.—RML. 18498

6.2.2, 3.7.2, 3.5.9

Oxidation of Iron-Molybdenum Alloys by Air at Elevated Temperatures. (In German.) Alfred Rahmel, Willi Jager and Kalus Becker. Arch. Eisenhuttenw., **30,** 351-360 (1959) June.

Retarding effect of molybdenum content on oxidation. Composition of surface layers after oxidation at different temperatures. 41 references.—RML. 18486

6.2.2, 3.2.3, 3.5.9, 3.7.3

Growth and Scaling in S. G. Iron. Pt. II. R. J. Mairland and I. C. H. Hughes. Iron & Steel, **32,** 100-103 (1959) March.

Critical temperatures determined by heating at various temperatures near the critical temperature range, followed by quenching in water. Relation of critical temperature to linear growth and scaling.—RML. 18404

6.2.2, 3.2.3, 3.7.2, 3.5.9

Growth and Scaling in S. G. Iron. The Influence of Silicon. Pt. I. R. J. Maitland and I. C. H. Hughes. Iron and Steel, **32,** 57-59 (1959) Feb.

Provided the exposure occurs below the critical temperature range, growth and scaling are inhibited by increasing silicon content. Above a maximum temperature, corresponding roughly with the critical temperature range, scaling and growth become catastrophic. Increasing silicon content raises the critical range and the safe maximum working temperature but also promotes both growth and scaling above this temperature.—RML. 18403

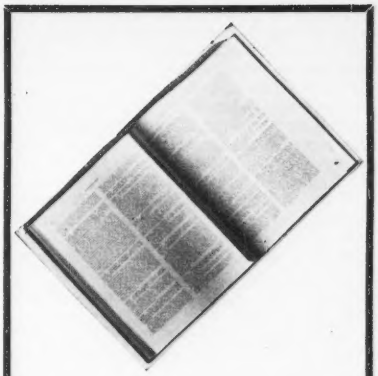
6.2.3, 4.2.3

Corrosion of Mild Steel in Sulphur-Containing Gas Streams. (In German.) T. K. Ross and A. J. Macnab. Werkstoffe u. Korrosion, **10,** 417-422 (1959) July.

In the gas soot process with no excessive air available considerable amount of hydrogen and carbon are present. At high temperatures sulfide cinder layers develop and in the presence of tension these layers break loose. Strong corrosion occurs on mild steel surfaces.—RML. 18524

6.2.5

AM-355: High-Strength Stainless, It Links Good Corrosion Resistance with Ease of Fabrication. G. N. Aggen. Allegheny Ludlum Steel Corp. Iron Age, **183,** No. 14, 74-77 (1959) April 2.



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Properties, fabrication and uses of high-strength low-alloy AM-355 stainless steel are discussed. Tensile properties, stress rupture and creep properties. Charpy U-notch impact strength and corrosion resistance are tabulated. Forging, heat-treating, machining and welding are discussed.—NSA. 18369

6.2.5, 3.8.3, 3.7.2, 3.2.2, 4.3.2

Use of Stainless Steels in Corrosion Control. J. P. Ogilvie. Paper before Can. Inst. Mining & Met., Annual General Mtg., Vancouver, April, 1958. Trans. Can. Inst. Mining & Met., **62,** 17-21 (1959); Can. Mining and Met. Bull., **52,** No. 562, 85-89 (1959) Feb.

Knowing that stainless steels are corrosion resistant as result of formation of a passive surface film of chromium oxide rather than because of an inherent inertness of alloy itself allows prediction with some certainty of fields of useful application. Other elements added to these steels have some influence on nature of passivating film; graphs show effect of nickel added to a 15 chromium steel on its resistance to neutral chloride solution and effect of molybdenum added to 19 chromium-9 nickel steel on resistance to sulfuric acid. Intergranular, pitting and crevice corrosion are considered, with reference to mechanisms of formation and preventive measures (carbide precipitation in austenitic stainless steels is examined in detail). Resistance to specific chemicals is discussed, including nitric, sulfuric, phosphoric and acetic acids, and sodium hydroxide (graphs and iso-corrosion curves give data for various stainless types.)—INCO. 18533

6.2.5, 4.3.2, 8.4.5

Corrosion of Type 316 ELC Stainless Steel in Fluoride-Bearing Zirconium Process Wastes. T. L. Hoffman and C. M. Slansky. Phillips Petroleum Co. U. S. Atomic Energy Commission Pubn., IDO-14449, Jan. 9, 1959, 20 pp. Available from Office of Technical Services, Washington 25, D. C.

A study was made of the life of the waste storage tanks under actual storage conditions in order to provide data for the design of future storage facilties. The work reported involved corrosion studies on specially prepared stainless steel samples and on stainless samples cut from weld coupons prepared at the tank fabrication site. Bench-type corrosion tests were run using synthetic hydrofluoric acid process waste solutions and boiling 65 percent nitric acid. The corrosion of stainless steels, in fluoride-containing process waste indicated type 316 ELC stainless steel as likely material for tank construction. More elaborate experiments are described under bench-scale and plant conditions.—NSA. 18433

6.2.5, 8.4.5

Thorex Pilot Plant Corrosion Studies: I. Corrosion of Types 304L and 309SCb Stainless Steel During Production and Development Periods. J. L. English. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-2673, May 12, 1959, 73 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

Corrosion behavior of types 304L and 309SCb stainless steel was examined during the production and first half of the development periods of Thorex pilot plant operation between December 15, 1954, and November 10, 1955. The process vessels in which corrosion data were obtained included the batch dissolver tank, the feed adjustment tank, the AP catch tank and the BT vapor separator. There was no significant difference between the corrosion resistance of the two alloys in any of the environments. Vapor-phase corrosion attack in some vessels was more severe than solution-phase attack in the same vessels. Dependent upon the particular process environment, corrosion rates in the vapor phase ranged from 0.1 to 46 mpy; solution-phase corrosion rates ranged from 0.1 to 28 mpy. The most severe attack in both solution and vapor phases occurred in the feed adjustment tank. There was serious corrosion in the BT vapor separator also. Corrosion was moderate (8 mpy or less) in the batch dissolver tank and was almost negligible (0.2 mpy or less) in the AP catch tank. The attack on rolled surfaces of both types of stainless steel was uniform, with the exception that shallow, intergranular penetration was experienced in the more corrosive environments. Edge-surface attack was intense in the latter environments also and introduced some question as to the validity of corrosion rates based upon total attack on specimens. Neither of the alloys, initially stressed at 35,000 psi, experienced stress-corrosion cracking in any of the environments, nor was there any evidence of a stress-induced acceleration in the rates of attack. Weld specimens of both alloys underwent preferential attack at the weld-parent metal interface in a number of the environments; the frequency of the attack was random in nature, however. Neither alloy was subject to crevice corrosion nor was accelerated corrosion at solution-vapor interfaces observed. (auth)—NSA. 18270

6.2.5, 3.2.2

Stainless Alloys, Present and Future. W. O. Binder. Paper before American Inst. Chemical Engrs., Golden Jubilee Mtg., Philadelphia, June, 1958. Chem. Eng. Progress, **54,** No. 11, 45-50 (1958) Nov.

Corrosion and metallurgical properties of stainless steels are discussed, and the properties of new stainless steels and high alloys are given and compared. Included in the discussion of properties are: stress-corrosion cracking and its prevention; effect of sigma- and chi-phase precipitation on strength, ductility and corrosion; intergranular corrosion and its prevention; and hot-shortness during welding. The new stainless steels described are: high-manganese, precipitation-hardening, special high alloy (high nickel, with molybdenum, copper and silicon), and ferritic high-temperature. High alloys such as Inconels, Alloy 805, Nimonics, Waspaloy, Udimet, Incoloy, Illium R and G, Ni-O-Nel, and Hastelloys are briefly discussed. Corrosion data from types 202 and 300 stainless steels in about 30 different chemical plant environments are tabulated.—NSA. 18197

6.2.5, 3.2.2, 3.6.6, 3.2.3

How to Select a Stainless Steel—Manual No. 155. J. L. Everhart. Materials in Design Eng., **49,** No. 1, 95-110 (1959) Jan.

Five important factors involved in choice of correct grade of wrought stainless steel for a specific application are: corrosion or heat resistance, mechanical and physical properties, ease of fabrication, availability and cost factors. General corrosion, intergranular corrosion, galvanic corrosion, pitting and atmospheric corrosion (including scaling) are discussed. Properties at room, low and high temperatures are considered (numerous tables and graphs give specific data). Fabrication methods include hot working, cold working, welding and machining. Information is given for austenitic, ferritic and martensitic grades. Numerous photographs illustrate specific applications, while general applications of the various grades are tabulated. Bibliography.—INCO. 18299

6.2.5, 3.8.3, 4.3.2

Effects of Oxygen on the Electrochemical Behavior of Stainless Steels in Sulfuric Acid. (In French.) Philippe Berge. Compt. rend., **249,** 262-264 (1959) July 15.

Polarization curves of 18-8 steels and measurements of the degree of passivity in coulombs/cm^2 for deaerated sulfuric acid are given. It is established that the rapid depassivation observed in acid media deprived of dissolved oxygen is due to a reduction of the passivating layer in the absence of stronger oxidants. Therefore the depassivation is not due to liberation of previously adsorbed oxygen. (auth)—NSA. 18209

6.2.5, 4.3.2, 3.7.3

Corrosion Resistance of Type 347 Stainless After "Sensitizing" Heat Treatments. H. F. Ebling and M. A. Scheil. A. O. Smith Corp. Metal Progress, **76,** No. 1, 94-97 (1959) July.

Effect of aging Type 347 for various lengths of time on its nitric acid corrosion resistance is shown. Although there have been many controversies over results of boiling nitric acid or Huey test, author justifies its use at A. O. Smith Corp. Two heats of Type 347 from different producers were tested; compositions are tabulated. Effect of reheating temperatures in 100 F increments from 700 to 1500 F is explored; tests on material reheated to higher temperatures for long time have not yet been completed, but time-temperature relationships do show definite trends. Nitric acid corrosion of Type 347, Heat A, in in. per year is tabulated and these data are plotted as temperature-contour curves and time-contour curves. By taking time-temperature relationship at any particular corrosion rate, a graph can be constructed showing contours of various corrosion levels as a function of time and temperature. Such diagrams (time-temperature-sensitization) are shown. Selected specimens of both heats were examined microscopically. It appears that Type 347 material is not wholly stabilized and far from immune to intergranular attack. However, Type 347 wrought material, under certain conditions, is most resistant of 18-8 austenitic materials as far as intergranular attack is concerned. TTS diagrams given may enable metals engineer to control heat treatment so as to avoid unexpectedly high rates of corrosion.—INCO. 18269

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3, 3.5.9, 3.2.2

Preliminary Investigations on the Properties of Chromium and Chromium Alloys at Elevated Temperatures. G. R. Wilms and T. W. Rea. J. Inst. Metals, **87,** No. 3, 77-78 (1958-59).

High temperature properties of chromium, and of chromium-10 percent

tungsten and chromium-5 percent molybdenum alloys, were assessed by tensile creep tests in air at 950 C. The alloys show considerable promise as high-temperature materials, on the basis of both strength and oxidation-resistance. Structural changes associated with the creep deformation of chromium and the alloys are similar to those previously observed in other metals. Intercrystalline cavities develop during creep, leading to intercrystalline fractures, but certain differences were observed between the cavities in the pure metal and those in the alloys. (auth)—MA. 17666

6.3.3, 3.8.4

Oxidation of Chromium in Air and Oxygen. V. I. Arkharov, V. N. Konev, I. Sh. Trakhtenberg and S. V. Shumilina. Fizika Metallov i Metallovedenie (in Russian.), **5,** No. 1, 190-191 (1957); Physics of Metals and Metallography (In English), **5,** No. 1, 164-165 (1957).

Oxidation was carried out at 700-1000 C and the kinetics of scale formation were studied together with the phase composition, texture and microstructure of the layers of scale. In air the rate of scale formation was reduced and the lattice parameter of the chromium oxide was increased, owing to the partial dissolution of nitrogen in chromic oxide. X-ray photographs of some specimens oxidized in air showed the presence of Cr_2N.—MA. 17917

6.3.5, 1.3

Niobium: The Medium-Rare Metal. Ind. & Eng. Chem., **49,** No. 10, 42A-47A (1957).

A general review of the development and use of niobium. Its chemical properties are emphasized and related to corrosion problems.—MA. 16224

6.3.5, 3.7.2, 3.5.9

Protection of Niobium Against Oxidation at Elevated Temperatures. Final Report on Protection of Molybdenum Against Corrosion at High Temperatures. Annual Report for the Period: July 16, 1956-July 15, 1957. J. W. Spretnak and Rudolph Speiser. Ohio State Univ. RF-Project 467, Report No. 15. Contract N6onr-225(28) (NR039-005). Available from Ohio State Univ., Research Foundation, Columbus.

Pure niobium sheet was oxidized in air to provide a basis of comparison with the oxidation behavior of the binary and ternary alloys prepared. The binary alloys in the niobium-zirconium system were prepared and oxidized. Alloys containing 90 wt. percent niobium and 80 wt. percent niobium were less resistant to oxidation than pure niobium. An alloy of 70 wt. percent niobium-30 wt. percent zirconium alloy had slightly better oxidation resistance than pure niobium at 860 C. Binary alloys in the niobium-titanium system were prepared and oxidized at 860 C. The oxidation resistance was found to be greater than pure niobium. The oxidation rate of niobium-molybdenum-silicon system was lower than pure niobium. The oxide films formed were not protective.—NSA. 18007

6.3.6, 3.5.8

Corrosion Cracking of Brass Under the Action of Cyanide Electrolyte. (In Russian.) A. V. Shreider. J. Applied Chem. USSR (Zhur. Priklad. Khim.), **30,** No. 5, 794-796 (1957). Translation Available from Consultants Bureau, Inc., 227 West 17th Street, New York 11, N. Y.

Shreider [ibid., **29,** 1044 (1956)] attributed the cracking of a fuel distributor to stress-corrosion in the ammonia-containing atmosphere. In the present investigation of fractures of another type of distributor made from cadmium-plated L68 brass, tubes of this brass were half immersed for 114 days in various media to which they would be exposed during manufacture of the distributors: supply water, aqueous dregs from the fuel (~1 percent alkali), electrocleaning bath, pickle liquors, brightening bath, cyanide cadmium-plating bath and welding flux. Corrosion products similar to those formed in service were only formed in alkaline media. Stress corrosion tests in the plating solution showed cracking of the tubes, indicating that the service failures could result from retention of traces of this solution. The corrosion products were blue $Cu_2(OH)_2$. carbon trioxide, cupric hydroxide and cupric oxide.—MA. 18003

6.3.6, 8.4.3, 3.4.8

Plant Corrosion Test of Copper Alloys on Petroleum Refining Unit. (In Japanese.) Yahiko Kadono. Corrosion Engineering, Japan, **8,** No. 1, 2-4 (1959) Jan.

Author studied the corrosion tendencies of copper base alloys in petroleum refining process by plant test.

Results obtained are as follows: 1. Copper-nickel alloys are sensitive against the corrosion under the temperature below 200 C and agitating condition. 2. Copper-nickel alloys suffer corrosion by hydrogen sulfide and other sulfur compounds. 3. Aluminum bronzes are not stable on the point of corrosion against alkaline compounds. 4. Admiralty alloys are most stable for petroleum refining process. 17629

6.3.6, 3.8.4

Oxidation of Copper in Aqueous Solutions of Potassium Dichromate and Sulfuric Acid. (In Russian.) N. N. Milyutin and A. I. Shultin. J. Applied Chem. USSR (Zhur. Priklad. Khim.), **30,** No. 3, 346-352 (1957). Translation Available from Consultants Bureau, 227 W. 17th St., New York 11, N. Y.

Specimens of copper were dissolved at 25 C in normal sulfuric acid containing 0.011-0.44 M-$K_2Cr_2O_7$, and the stationary potential (ϕ, in V.) measured as in the experiments on dissolution in nitric acid [Milyutin and Shultin, **Ibid.,** No. 1, 58 (1957)]. For dichromate concentrations of 0.011-0.1M, $\phi = 0.195 + 0.056 \log v$, where v is the dissolution rate in g/m²/hr; at higher concentrations the reaction products retarded the process and the relation was no longer linear. Stirring the solution did not prevent this retardation but it could be avoided by using 3N-acid at 35 C. The strong increase in dissolution rates on stirring the solution and the value of the temperature coefficient of the reaction indicated that v was determined both by the rate of diffusion of the oxidant and by the rate of the electrochemical reactions at the copper surface.—MA. 17901

6.3.6, 3.2.2, 4.6.2

Licking the Problem of Stress-Corrosion Cracking of Aluminium Bronze. John F. Clement, Robert E. Maerson and Patrick A. Tully. Metal Progress, **75,** No. 2, 82-86 (1959).

Laboratory tests and service trials with pressure vessels show that intergranular stress-corrosion cracking of aluminum bronze containing aluminum 7, iron 2 percent in steam at temperatures up to 500 F (205 C) can be prevented by the addition of tin 0.35 percent.—MA. 18360

6.3.6, 3.7.2, 6.2.2, 3.5.9

Influence of Silicon on the High-Temperature Oxidation of Copper and Iron. J. W. Evans and S. K. Chatterji. University of Manchester, England. J. Electrochem. Soc., **106,** 860-866 (1959) October.

Effects of 1 at. percent of silicon on the oxidation behavior of pure copper at 850-1000 C and of pure iron at 950-1200 C have been studied by means of a thermobalance. Silicon has a marked effect on the oxidation of iron but relatively little on that of copper. The distinctive behavior is attributed mainly to the different diffusivities of oxygen in the base metals. The depth of subscale formed in the iron alloy suggests that the diffusivity of oxygen in iron is much faster than is commonly supposed.— 18263

6.3.6, 4.4.2, 4.3.2, 5.8.3, 5.8.4

Effect of Various Protective Colloids on the Corrosion of Brass. (In German.) M. N. Desai, J. D. Talati and A. M. Trivedi. Werkstoffe u. Korrosion, **10,** No. 1, 26-29 (1959) Jan.

Corrosion of 70:30 brass by 0.2 N-citric acid for 5 hours in the presence of various concentrations of gum arabic, egg albumen, gelatine, agar-agar, dextrin, and potato starch was studied. All reduce the attack, the inhibiting action falling off in the order given. The action fits an adsorption relation $x/m = K(c)\frac{1}{n}$, where K and n are constant, c concentration of colloid, and $x/m \propto$

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inhibitory effect. For normal hydrochloric acid and 67 hours the attack is increased by the colloids in a 0.2 percent concentration accompanied by dezincification. At greater colloid concentration inhibition might take place for hydrochloric acid attack. 16 references.—MA. 18362

6.3.8, 4.6.1, 4.3.6

Corrosion of Lead Pipe. (In German.) Edith-Luise Schmeling and Benno Roeschenbleck. Werkstoffe u. Korrosion, **9,** No. 8/9, 529-532 (1958).

Results of corrosion tests on lead in distilled water, hard water, and solution of sodium carbonate, sodium monosulfide, $Ca(HCO_3)_2$. Weight loss and appearance after 62 days are tabulated. Measurements of current density/voltage curves for lead in various waters are described, and conditions given for which the use of lead pipes is unsuitable.—MA. 17728

6.3.10, 3.8.4

Oxidation of Nickel by Ionic Bombardment. (In French.) J. J. Trillat, L. Tertian and N. Terao. Cahiers de Physique, No. 92, 161-162 (1958) April.

Thin film of nickel resting on support of sodium chloride was bombarded in electron diffractograph by ions from surrounding atmosphere; heating of specimen was avoided by sweeping ion beam. Bombardment provoked formation of a NiO oxide film oriented according to lattice of the metal, and progressively removed the surface layers of oxide thus formed without modifying their structure. Under conditions of experiment, appearance of Ni_3N does not occur, contrary to case of bombardment of thin film of nickel without supporting material. 7 references.—MR. 17605

6.3.11, 3.8.4

Formation of Zones of Internal Oxidation in Silver-Indium Alloys. (In German.) Isolde Dietrich and Lisl Koch. Z. Metallkunde, **50,** No. 1, 31-35 (1959).

Internal oxidation of binary alloys of silver with up to 8 percent indium, after heating at 450-850 C. in air for up to 5 hr. was studied by metallography and electrical-resistance measurements. For alloy contg. <6 percent indium and at temp. <400 C oxidation conforms to a parabolic time-law and an exponential temperature-dependence, while the data are in good agreement with the observations of Rhines and Grobe (Trans. Amer. Inst. Min. Met. Engrs., **137,** 318, 1942.) that diffusion of oxygen is the rate-determining factor.—MA. 17742

6.3.6, 8.1.2, 4.2.1

Copper as Roofing Material. K. Eichhorn. Pro-Metal, **11,** No. 65, 35-39 (1958).

Corrosion resistance of copper to prolonged atmospheric exposure is discussed and the formation and function of the patina is considered in detail. All commercial grades of copper can be used for roofing sheet, and fasteners must also be of copper. Roof-laying techniques are governed largely by thermal-expansion considerations.—MA. 18036

6.3.10, 3.8.4

Oxidation Studies on the Nickel-Chromium and Nickel-Chromium-Aluminum Heater Alloys. Earl A. Gulbransen and Kenneth F. Andrew. Westinghouse Electric Corp. J. Electrochem. Soc., **106,** 941-948 (1959) Nov.

A systematic study was made of the oxidation resistance of five 80 nickel-20 chromium heater alloys and one 4 aluminum-19 chromium-77 nickel alloy. Kinetic and crystal structure studies were made over the temperature range of 500 to 1100 C. The adhesion of the oxide film to the alloy was tested by the strain oxidation technique and the over-all performance was evaluated by the ASTM useful life tests. The rate of oxidation of the several alloys could not be correlated with the ASTM useful life results, while the strain oxidation tests could be correlated with the ASTM useful life tests. Chromic oxide was the major oxide formed on the 80 nickel-20 chromium alloys at 1100 C. Although aluminum oxide and chromic oxide were observed below 1000 C on the 4 aluminum-19 chromium-77 nickel alloy, no aluminum oxide was observed in the oxide scale at 1100 C. A thermodynamic and kinetic interpretation was made of the results. 18291

6.3.13, 3.4.6, 3.2.3

Tantalum-Oxygen System. (In German.) Erich Gebhardt and Hans-Dieter Seghezzi. Z. Metallkunde, **50,** 248-257 (1959) May.

Tantalum was oxidized by pure oxygen at 700-1420 C under pressure. Three simultaneous reactions occur—formation of an outer oxide layer of tantalum pentoxide, growth of an oxide subscale of laminated structure in cubic tantalum and dissolution of oxygen in tantalum. 33 references.—RML. 18284

6.3.11, 3.7.2

Silver-Indium Alloys. A Contribution to the Question of Oxide-Resistant Silver Alloys. (In German.) Ernst Raub and Alice Schall. Z. Metallkunde, **30,** 149-151 (1958). Translated by S. E. Piel, Westinghouse Electric Corp. U. S. Atomic Energy Commission Translation No. 3419.

The effect of indium on corrosion properties of silver was studied. Workability of silver-indium and silver-indium-copper alloys is reported. Experiments in electrolytic precipitation of indium and silver-indium were not successful in producing a satisfactory coating.—NSA. 17560

8. INDUSTRIES

8.1 Group 1

8.1.1, 6.4.2, 5.11, 7.4.2

Performance of Aluminum in Air Conditioners. D. G. Vandenburgh and A. J. Haygood. Refrig. Engineering, **66,** No. 9, 42-47, 72-76 (1958); Chem. Absts., **52,** No. 22, 19800 (1958) Nov. 25.

Controlled service tests of various aluminum designs in evaporator and condenser coils have shown that properly designed aluminum coils are suitable for this service. Tests, made in three environments under conditions more corrosive than encountered in normal service, also showed the desirability of aluminum construction for other components of the air conditioner. In all cases performance of aluminum was enhanced by designing the air conditioner to eliminate known hazards. Two most effective designs incorporate either the more corrosion-resistant alloy tube or protection of the tube by both anodic aluminum alloy fins and suitable plant coatings.—ALL. 17597

8.1.2, 5.4.5, 5.3.2, 5.4.2

Corrosion Protection of Steel Parts Used in Building. (In French.) P. Blancheteau. Corrosion et Anti-corrosion, **6,** No. 6, 191-202 (1958) June.

Different iron and steel products used in building; anti-corrosive coating of structural steel. Use of paints, varnishes, metallic layers and vitreous enamels. Preparation of surfaces by mechanical and chemical processes.—BTR. 16432

8.1.2, 5.4.8

Protective Coatings for Buildings in Industrial Atmospheres. D. D. Veljkovic. Zastita Materijala, **6,** No. 2, 83-86 (1958).

The author discusses the factors influencing the durability of coatings used on buildings exposed to industrial atmospheres. The most widely used coatings and their properties are given. An analysis of the economics and utility of such coatings is made.—RPI. 16696

8.1.2, 6.3.8, 6.3.6

Copper Replaces Lead in Pentagon Re-Roof Job. L. E. Gichner. Heating and Air Conditioning Contractor, **50,** No. 1, 70-73 (1958) October.

In one of the biggest roof repair jobs on record, much of the lead, slate and slag roofing on Washington's mammoth Pentagon building was replaced. Hard copper has gone into service in place of the disintegrated lead. Installation of a mile of hard 16 oz. copper on ridge caps of the double-pitched slate roofs is described. Photos.—INCO. 17339

8.1.3, 4.3.3, 4.3.6, 4.4.3, 5.8.1

Corrosion Studies in Refrigeration Practice. A. G. Arend. Corrosion prevention and Control, **6,** No. 2, 33-35 (1959) Feb.

Review of the subject covers: nature of the solutions contended with (sodium chloride and calcium chloride brines, ammonia solutions, alcohol materials) and corrosion inhibitors added to them; use of aluminum in modern refrigerators; corrosion of iron and steel components by ammonia; and problems with copper components.—INCO. 18343

8.1.4, 3.2.2, 6.2.2

Corrosion in Water Engineering. A. W. Neal. Corrosion Prevention and Control, **5,** No. 10, 46-48 (1958) October.

Striking example of longevity of cast iron pipes is 1½-in. diameter main in service over 150 years in Gloucestershire. Examples of types of corrosion (tubercelation and graphitization of cast iron, plug dezincification of brass union) are shown. Protective coatings applied to cast iron and steel piping are considered, and use of cathodic protection discussed. Treatment of water is mentioned.—INCO. 17522

8.3 Group 3

8.3.3

Food Process Operations Demand Maze of Piping. R. M. Lazar. Carnation Co. Heating, Piping and Air Conditioning, **30,** No. 3, 105-109 (1958) March.

At Carnation Co.'s new Seattle fresh milk and ice cream plant, complex piping serves 4 separate water systems for various applications, a general purpose air system for instruments and agitation of raw milk, and ice cream batch mixing and paper milk carton coating systems. Design requirements were that systems operate automatically, be easy to maintain, be sanitary and neat appearing. Standard weight black pipe is used for all steam and condensate piping. Hot,

cold, process cold and hose rack hot water systems use galvanized pipe and bronze valves. Liquid sugar is stored in steel tank; pumps are bronze and piping is copper. Corn syrup is stored in black iron tank; pump has bronze fittings and piping is galvanized iron. Liquid coating wax is stored in black iron tank enclosed in steel jacket; piping is of aluminum tubing. Pipe and fittings for milk and its byproducts are of Type 302 which is polished to No. 4 finish.—INCO. 16551

8.3.5, 4.3.3, 3.4.8, 4.4.2, 6.2.5

Corrosion in the Food Industry. J. W. Selby. Food Manufacture, **33,** 403-410 (1958) October 1.

Principal corrosive constituents encountered are atmospheric oxygen, organic acids, chlorides, labile sulfur and sometimes sulfur dioxide (used as a food preservative). The 18-8 chromium-nickel steels with molybdenum show the greatest resistance to most acid chloride conditions and will even give fair service when sulfur dioxide is present. Corrosive behavior of nickel, Monel, Inconel and tin analyzed. 7 references.—MR. 17664

8.3.5, 6.3.14

Mechanism of Corrosion of Tin Plate by Various Food Products. R. P. Frankenthal, P. R. Carter and A. N. Laubscher. Paper before American Chemical Society, 134th Meeting, Ind. & Eng. Chem. Div., Chicago, September, 1958. J. Agr. Food Chem., **7,** No. 6, 441-442 (1959) June.

Corrosion mechanism of tin plate under conditions duplicating normal canned-food packs was studied. In grapefruit and tomato juice, dissolution of tin coating is accompanied by evolution of hydrogen; in prunes, hydrogen does not appear to be evolved when tin dissolves, but only when steel base is attacked. In prunes, all tin plates detin at same rate. In grapefruit and tomato juice, rate of detinning varies depending on type of tin plate. Electrochemical data indicate presence of depolarizers in prunes, but not in grapefruit juice, fact that explains different corrosion mechanisms. Graphs.—INCO. 18279

8.4 Group 4

8.4.1, 4.2.3, 7.6.4, 7.1, 3.5.2

Corrosion and Deposits in Coal and Oil-Fired Boilers and Gas Turbines. Battelle Memorial Institute. Report of ASME Research Committtee on Corrosion and Deposits from Combustion Gases. Book, 1959, 198 pp. Available from: American Society of Mechanical Engineers, 29 W. 39 St., New York 18, N. Y.

Mineral constituents in coal and heavy-fuel oil and their behavior during combustion; the action of sulfur dioxide and sulfur trioxide; physical aspects of deposition; origin and composition of deposits and their prevention; corrosion of metals exposed to combustion gases below 400 F and removal of solids from combustion gases turbines or air heaters. 349 references—RML. 18234

8.4.5

Aqueous Reprocessing of Nuclear Fuels. Charles L. Peterson, P. D. Miller, E. L. White and W. E. Clark. Paper before Symposium on "Reprocessing Chemistry for Irradiated Fuel, Aqueous Methods," Am. Chemical Society, 133rd Mtg., San Francisco, Calif., April, 1958. Ind. & Eng. Chem., **51,** No. 1, 32-37 (1959) Jan.

A feasible corrosion-resistant container material for the single-unit Zircex hydrochlorinator-dissolver is not apparent at present. Of the materials studied, the best choice is Haynes 25. Its use would require that penetration rates of approximately 3 mils per month be tolerated. The process should be run in two steps. Several materials, such as Inconel, Haynes 25, Type S-816, Illium R, and nickel, appear promising for construction of the hydrochlorinator. The cold residue would then be dissolved by transferring it to a container made from titanium or tantalum. Preliminary experiments in the alternate liquid-phase Zircex hydrochlorination system employing fused aluminum chloride-ammonium chloride indicate that nickel and the Hastelloys may be satisfactory for construction of the hydrochlorinator. Molybdenum appears even better from a corrosion standpoint. In the Darex system unalloyed titanium appears highly satisfactory for any part of the apparatus, with expected maximum corrosion of about 0.1 mil per month. No deleterious effects are expected around weldments or at points of high stress levels. The siliceous scale which forms in the dissolver can be removed by treatment with boiling 10 percent sodium hydroxide with no adverse effect on the corrosion resistance of the titanium. Corrosion rates for tantalum are negligible in all cases, but this metal is subject to hydrogen embrittlement when employed as the dissolver material. Other possible materials of construction are Haynes 21, with a corrosion rate of less than 0.5 mil per month, and Type S-816, with less than 1 mil per month. These results are derived from laboratory scale experiments. Pilot-plant evaluations on a larger scale are recommended prior to any plant construction based on these data. (auth) —NSA. 17732

8.4.5

Safeguards Aspects of PWR Reactor Coolant Chemistry. W. T. Lindsay. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-SC-546, June, 1957, 23 pp. Available from Office of Technical Services, Washington, D. C.

In the Pressurized Water Reactor (PWR) light water serves as both moderator and as coolant. The water at the same time participates in a variety of chemical process of concern in the design and operation of the reactor. These include corrosion of the primary coolant system, mechanisms, and fuel elements; radiation chemical reactions involving dissociation and synthesis; nuclear reactions and induced radioactivity; transport and fouling due to formation of plant corrosion products, and fuel element failure and release of fission products. Each of these processes involves potentially undesirable consequences for pressurized water reactors. In the development of PWR in particular, and pressurized water reactors in general, these processes have been examined, and water conditions and plant systems have been developed to reduce the extent and consequences of these processes to acceptable levels. The considerations involved in normal plant operation, with normal water conditions are discussed first. Secondly, the results of possible temporary variations from the desired mode of operation are considered in terms of their effect on plant safety. Some of the water conditions which may result from improper operation can have undesirable effects, such as increased general corrosion, causing accelerated foulings of heat transfer surfaces or decreased accessibility resulting from radioactive contamination of plant internal surfaces. However, no plausible deviation from the normal water conditions will have immediate undesirable effects, with the result that temporary excursions from the desired set of conditions may be tolerated for the period of time required for detection of the deviation and correction to the desired conditions. Nevertheless, since corrosion fouling and contamination are cumulative processes, every effort is made to reduce to a minimum the period during which the plant may be operating with water conditions other than normal. The consequences of fuel element failure are discussed. It is shown that operational limitations will not arise which can deny access if as many as 1000 blanket fuel rods contain defects in the cladding. (auth)—NSA. 15384

8.4.5, 4.4.1

Operational Experience with a High Temperature Organic Loop. J. L. Poe. General Electric Co., Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-55245, March 6, 1958, 11 pp. Available from Office of Technical Services, Washington, D. C.

Facilities were established for evaluating high-temperature organic coolants for both in-reactor and out-of-reactor testing. The organic recirculation apparatus for an out-of-reactor high-temperature loop was designed to determine the corrosive effects of organic compounds on reactor components and fuel cladding materials. A description of the equipment and operation of the loop are presented.—NSA. 17548

8.4.5, 6.2.3

Field Corrosion Tests in Redox and Purex Underground Waste Storage Tanks. Norman D. Groves, Morris C. Fraser and William L. Walker. General Electric Co. U. S. Atomic Energy Commission Pubn., HW-37642, June 28, 1955 (Changed from Official Use Only March 22, 1957), 10 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

A corrosion-testing program has been initiated in Purex and Redox storage tanks to obtain corrosion data on carbon steel and three associated materials in neutralized process wastes.—NSA. 17960

8.4.5, 6.2.5, 6.3.20, 4.3.3, 3.5.4

Homogeneous Reactor Experiment. Quarterly Progress Report for Period Ending Nov. 30, 1950. C. E. Winters and C. H. Secoy, Editors. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-925, Jan. 30, 1951 (Declassified March 2, 1957), 317 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion studies include studies of protective treatments for stainless steels, corrosion resistance of stainless steels, zirconium and reflector materials and corrosion in uranyl sulfate systems. Radiation stability and in-pile corrosion tests are described. Results of the tests are briefly summarized. Pictorial results of the work done on induction methods of soldering and of pretreated and corrosion-tested stainless steel are included. —NSA. 17977

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(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

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Topic of the Month

Sodium Chromate Inhibitor In an Ethylene Glycol Engine Coolant

By LEONARD C. ROWE*

Abstract

Laboratory tests were made to determine the suitability of sodium chromate inhibitor for ethylene glycol engine coolant. In the presence of light, chromate solutions turned green and dichromate solutions formed greenish precipitates. In the absence of light, little color change was noted.

Following completion of laboratory testing, eight-month long tests were made in automobile cooling systems. Methyl alcohol and ethylene glycol antifreezes were tested separately after addition of chromates. Indications were that chromate inhibitors could be used with ethylene glycol in the absence of light in cases where a laboratory evaluation had been made of operational factors. 5.8.2

Introduction

SODIUM CHROMATE salt is sometimes used to inhibit automotive engine coolants. Darrin pointed out that when this is done, certain denaturants and antifreezes may reduce the hexavalent chromium to the trivalent state.[1]

Best and Roche reported on the practicability of using the chromate inhibitor in methanol antifreeze solutions.[2] It had been thought formerly that this additive should not be used in an ethylene glycol solution because of the insoluble product which often forms during laboratory testing. A contradiction of this has been reported on the basis of limited service experience where it is claimed that chromates can be used with glycol antifreeze coolants.

Qualitative tests show that the rate of the reaction between the chromate compound and ethylene glycol is dependent upon heat, pH and the catalyzing effect of light. The reaction rate increases with an increase in temperature, a decrease in pH and the presence of light. It has been shown qualitatively that the trivalent chromium compound is soluble in solutions having a pH above 8 and increasingly insoluble as the pH drops below 8.

Effect of Light

The effect of light on chromate inhibitors in the presence of ethylene glycol was determined by exposing only one of two solutions to light at room temperatures. The chromate salt was added at a concentration of 0.5 percent to a 50 percent solution of ethylene glycol. Sodium chromate gave a solution pH of 8.5 and sodium dichromate one of 4.2.

Within a few hours after the solutions were exposed to sunlight a green color was detected in the chromate solution and a green precipitate in the dichromate solution. The reaction was more rapid in the dichromate solution because of the lower pH.

The intensity of the green color or the degree of precipitation increased with time until the reaction was complete. In the absence of light the solutions remained clear with their original color for a period of weeks. Eventually a trace of color or precipitate could be observed which might have been due to momentary exposures to light when viewing the solutions. After four months a slight reaction was indicated although the solutions retained, in general, their original colors. When these solutions were removed from the light excluded area and exposed to light, they immediately showed a rapid reaction.

Automotive Tests

To further substantiate these results, four automotive tests were conducted for a period of eight months. Sufficient technical grade glycol was added to the cooling system to give a freezing point of minus 10 degrees F. Two cars contained methyl alcohol and two ethylene glycol. A direct sodium chromate addition was made to one of each type antifreeze to give a chromate concentration of 2000 ppm. The other two cars had commercial by-pass filters installed which leached chromate into the system. Samples were taken periodically for observation. In all cases the solutions varied from yellow to orange in color. A green color should be in evidence if a trivalent chromium product is produced since the pH is on the alkaline side.

A comparison of the final coolant samples is shown in Table 1. It is evident from these data that much of the chromate is depleted from the systems having a single addition. This indicates the need for recharging after the initial addition. The filter elements used in the other two tests were changed once during the test period and this maintained the chromate at an active level.

Because there was a substantial increase in the final pH, it can be argued that reduction occurred in the two cars in which a filter was not used. This can not be refuted entirely except for the lack of a green color and the absence of trivalent chromium in the final coolant sample. Since a pH rise occurred in both types of antifreeze and it has been shown that chromates can be used with methyl alcohol systems,[2] it is reasonable to believe that the chromate was utilized in a protective film formation and the increased pH was a result of the reaction. A direct comparison with the other two tests is not applicable since the extra addition of chromate or the presence of other constituents in the filter element may have influenced the final pH.

Conclusions

These results are only an indication that chromate inhibitors can be used with ethylene glycol in the automotive coolant where light is excluded. Since the chromates are susceptible to reduction, their use with foreign materials or other commercially inhibited antifreezes is not recommended unless thoroughly tested first.

All operational factors must be taken into consideration in attempting a laboratory evaluation. The presence or absence of light is a factor that must be taken into account.

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TABLE 1—A Comparison of Chromate Inhibited Samples After an Eight Month Automotive Service Test

Car. No.	Antifreeze	Filter	pH, Initial	pH, Final	Color	Chromate, ppm
1	Methyl alcohol	No	8.8	10.7	Pale yellow	21
2	Methyl alcohol	Yes	8.7	8.7	Yellow	975
3	Ethylene glycol	Yes	8.0	8.8	Yellow	451
4	Ethylene glycol	No	8.3	10.5	Pale yellow	5.4

* Research Laboratories, General Motors Corporation, Warren, Michigan.

Effect of pH on Oxygen Corrosion At Elevated Pressures*

By O. L. RIGGS, JR., J. D. SUDBURY and MERLE HUTCHISON

Abstract

A summary study of oxygen corrosion of mild steel in brine is presented. Corrosion rates were determined for oxygen pressures ranging from atmospheric to 515 psia and over a pH range of 1-13.5. All tests were conducted at room temperature (24 C).

It is shown that corrosion rates are generally increased with increasing oxygen pressure and decreasing pH; however, when tests exceeded 6 hours duration, an accelerated corrosion developed over the pH range 8-12. An unusual filamentary type corrosion product develops and grows in the 300-500 psi oxygen pressure range in pH 12 system. The identification and proposed mechanism of growth are given.

3.4.6

Introduction

DISSOLVED OXYGEN is considered to be a controlling factor in the aerobic (oxygen) corrosion of steel in water. The severity of the corrosion depends largely on the amount of oxygen dissolved in the water. Both oxygen and water must be present. Either ingredient is considered noncorrosive in the total absence of the other at ambient temperatures. Other factors which have an effect are conductivity, velocities, pH, temperature, etc.

The corrosion process of steel in aqueous media and oxygen is electrochemical in nature, the corrosion of the steel being accomplished by the action of a network of cathodic and anodic cells on the metal surface. A drawing of an oxygen concentration cell (Figure 1) diagrams the mechanism of oxygen corrosion. The basis for corrosion is attributed to the difference in oxygen concentration. At the anode, oxidation occurs and the area is low in oxygen concentration. This permits a difference in potential to exist because of higher oxygen concentration at the cathode. The theory proposes that metal ions go into solution at the anodes of these cells in an amount which is chemically equivalent to the reaction at the cathodes.

The reaction which takes place at the anode of an iron surface is:

$$Fe - Fe^{++} + 2(e^-) \qquad (1)$$

The rate at which this reaction takes place is controlled by the reaction rates at the cathode. The reaction at the cathode is typical of either of the following:

$$H^+ + (e^-) - H^\circ \qquad (2)$$

$$2H^\circ + \tfrac{1}{2} O_2 + - H_2O \qquad (3)$$

Reaction (2) is slow in near neutral and alkaline media but quite rapid in acids. The cathodic reaction rate can be increased by a process of depolarization as the dissolved oxygen reacts with the H° at the cathode surface.[1] Precipitation of the dissolved iron occurs at the partition between the anode-cathode areas. The over-all corrosion rate is proportional to the rate of diffusion of oxygen to the metal surface. The diffusion rate is, of course, dependent upon the concentration of dissolved oxygen present in the aqueous environment.

Considerable work has been reported on oxygen corrosion at atmospheric pressures. The corrosion rate of iron, when the oxygen concentration is 10 ppm or less, is considered linear.[1,2,3,4,5] The effect of temperature[6] and pH[7,8,9,10] has a direct relationship on the reaction rate of ferrous iron and oxygen. Certain types of domestic waters at slightly basic pH's are more corrosive to steel than when the waters are slightly acidic. The rate of the corrosion of steel in these basic waters increases with increasing chloride concentration.[11,12]

The corrosion rates of steel and composition of corrosion product were reported to be affected by velocity.[10,13,14] Some information is available on the corrosion of steel at elevated pressures.[15,16,17,18,19] The corrosion rate of steel steadily increases as the pressure of oxygen increases, up to 20 atmospheres, at which the growth of rate with increased pressure becomes less rapid. Other controlling factors on corrosion

★Submitted for publication November 30, 1959. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Denver, Colorado, October 12-15, 1959.

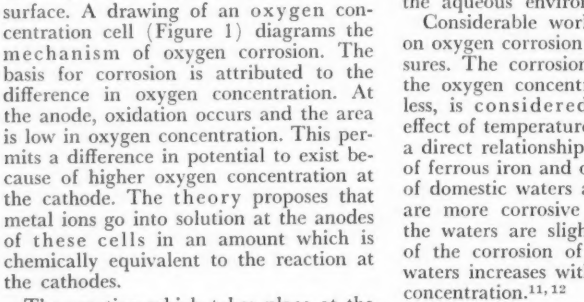

Figure 1—Mechanism and reaction of oxygen corrosion.

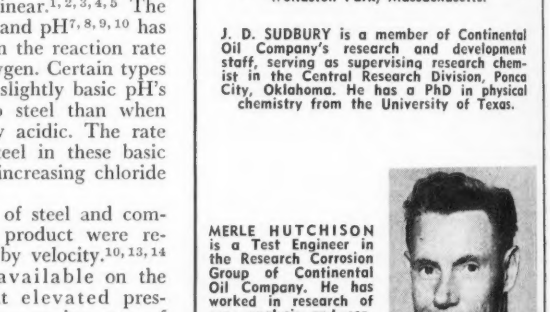

Figure 2—High pressure corrosion apparatus.

Riggs

Sudbury

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MERLE HUTCHISON is a Test Engineer in the Research Corrosion Group of Continental Oil Company. He has worked in research of core analysis and corrosion involving all phases of petroleum operations.

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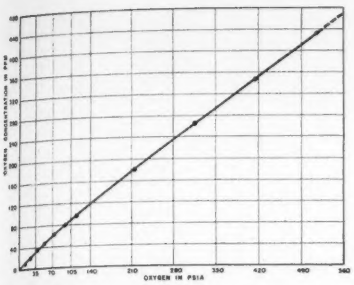

Figure 3—Conversion psia oxygen to ppm (Henry's Law).

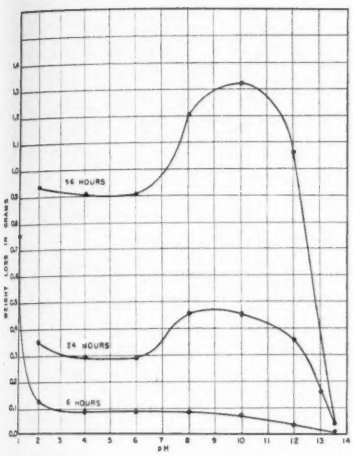

Figure 4—Effect of time on corrosion of 1020 mild steel at 515 psia oxygen and various pH levels (with agitation).

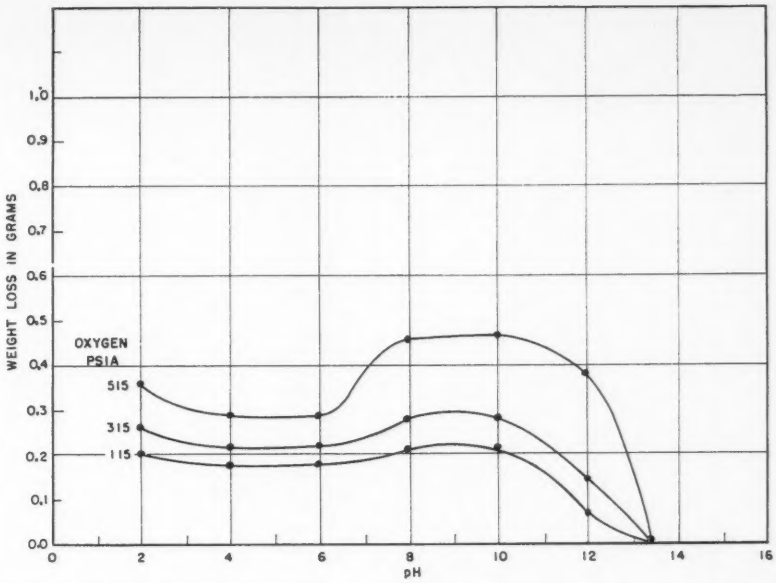

Figure 5—Effect of pH on corrosion of 1020 mild steel at various oxygen psia (24 hours with agitation).

rates are a function of passivity.[15, 20] It also has been concluded that steels in aerobic corrosion fatigue service will have longer service life in systems with high pH levels.[21]

A further knowledge of the effects of higher pressures of oxygen on the corrosion of steel was desirable for a better understanding of problems caused by the use of aerated drilling muds.

Experimental

The oxygen pressure equipment is shown by a schematic drawing in Figure 2. Each of the five stainless steel pressure cells was maintained at a given constant pressure and temperature. The solutions were agitated at a velocity of about 3-5 feet per second with a magnetic stirrer. The gas (oxygen) was allowed to flow by opening slightly the bleed-off valve of manifold. The rate of gas exhaust was measured through a borosilicate and stainless steel gas flowmeter.

Each cell was constructed with a valve on the inlet and outlet tubes for the purpose of possible removal of individual test samples. This was done without interruption of total test.

The test samples were ½-inch by 3-inch strips of SAE 1020 cold rolled mild steel. A 1/16-inch hole was drilled, centered at one end of the test strip for mounting on a lucite holder.

Synthetic brine was prepared by dissolving 5 percent by weight sodium chloride per volume of demineralized water. The water was adjusted to the desired pH by use of dilute HCl or NaOH. Each cell was filled with 200 ml of the brine prior to inserting test sample and sealing with cap.

The samples were prepared for the corrosion test by abrading to uniform surface with a mechanical belt sander. A 50 grit aloxite belt was used first to free coupon of mill scale; then an 80 grit belt was used to finish the surface. Each sample was numbered and its weight recorded before and after exposure in the corrosion test cell. The cleaning of sample was accomplished by dipping in HCl inhibited with 3 percent dibutylthiourea, scrubbing with soft-bristle brush and cleanser, rinsing in hot water, dipping in acetone, and then drying in a jet of air. Evaluation of sample was determined by (1) weight difference, (2) observation of surface corrosion, and (3) type or form of corrosion product.

The regulator was so constructed to maintain the adjusted cell pressure within ±1 psi. The exhausted gas flow was adjusted to 0.5 liter per minute by use of a plastic-tipped, stainless steel, needle valve.

Solubility of Oxygen in Brine

Oxygen functions basically in aerobic corrosion to: (1) depolarize the cathodes by reaction with hydrogen and (2) oxidize ferrous ions to the ferric state. Oxygen pressure being present in excess of atmospheric conditions necessitates the use of Henry's Law ($m = kp$) which is reported not entirely applicable to the high pressure[22, 23] to establish the oxygen solubility. The solubility of oxygen was calculated, ignoring the effect of pH and using the formula for oxygen solubility at atmospheric pressure[24] taken from the International Critical Tables, First Edition, McGraw-Hill Book Co. (1928), Volume III, page 272:

$$So_2 = 10.291 - 0.2809t + 0.006009t^2 + 0.0000632t^3 - \pi Cl(0.1161 - 0.003922t + 0.0000631t^2)$$

Where S is solubility of oxygen in cm^3/liter, t is temperature in the range 0 to 28 C, Cl is the concentration of Cl^- in the concentration range 0 to 20 parts per thousand and $\pi = 3.1416$. Using this equation, the oxygen solubility at 25 C in a 30 parts per thousand brine was calculated to be 4.319 cm^3/liter (0.00617 g. O_2/liter). This calculated solubility value agrees with extrapolated value of Fox.[24]

Using this value, the K for Henry's Law ($M = Kp$) was determined to be 6.17×10^{-3} g./liter atmosphere. Oxygen

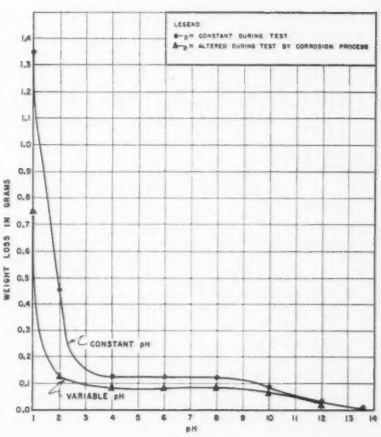

Figure 6—Effect of constant pH intervals on corrosion of mild steel in brine at 515 psia oxygen (6 hours with agitation).

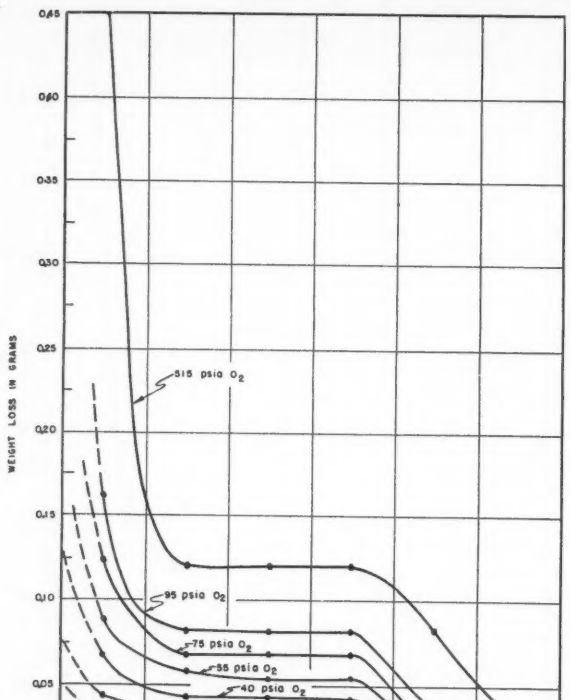

Figure 7—Effect of constant pH intervals on corrosion of 1020 mild steel in brine at various psia oxygen (six hours with agitation).

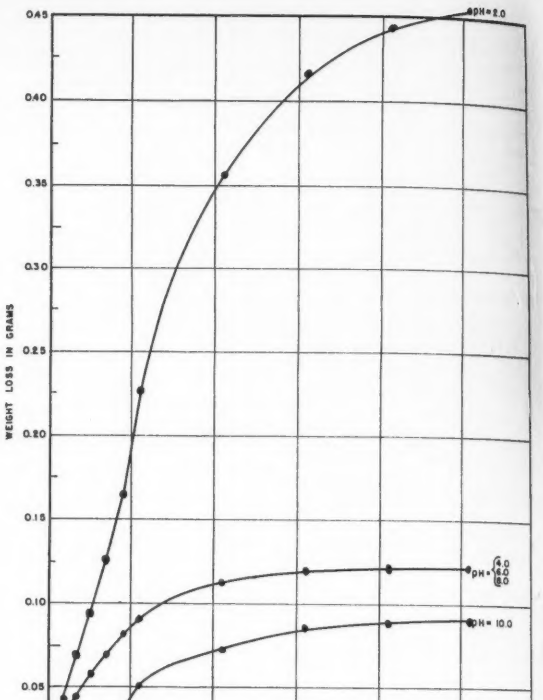

Figure 8—Effect of various amounts of oxygen on corrosion of 1020 mild steel in brine at intervals of constant pH (6 hours).

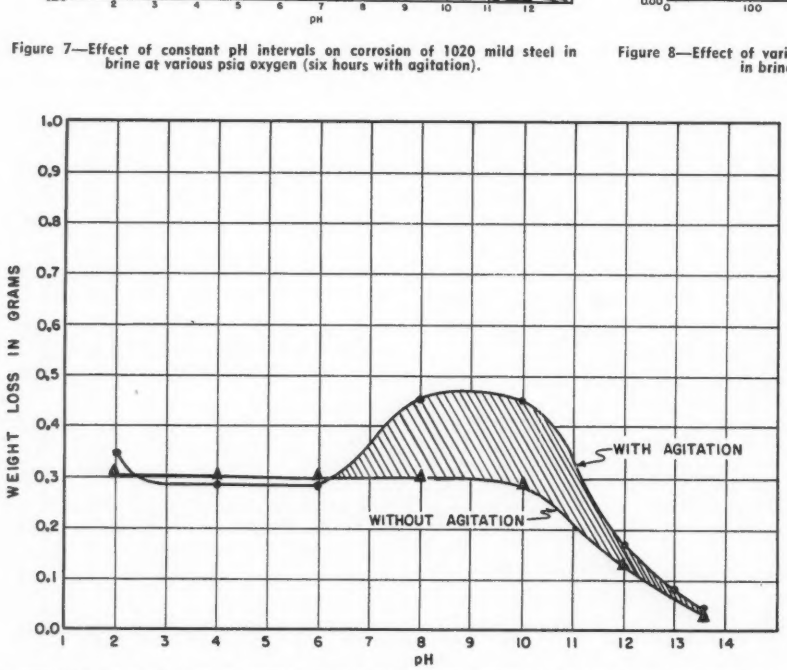

Figure 9—Effect of agitation on corrosion of 1020 mild steel at various pH and 515 psia oxygen (24 hours).

solubilities over the pressure range 0 to 500 psi were calculated and are plotted in Figure 3.

Effect of Oxygen and pH on Corrosion Rate

Data were taken to determine the corrosivity of various concentrations over a wide range of pH. The data in Figure 4 show the relation between corrosion rate and pH at 515 psia oxygen. The curve obtained after 6 hours was as expected. The corrosion rate was very high at low pH, constant over the middle pH range, and decreased to near zero in alkaline solutions. When these same experiments were carried out for 24 hours, it was shown that the corrosion rate began to increase over the pH range 8-10. This acceleration trend is even greater after 96 hours. This point seems very important, since it is a popular concept that at pH's above 10, oxygen corrosion of steel does not occur. This acceleration effect is even more serious, since the corrosion is a highly localized rather than general corrosion over the entire metal surface. This effect has not been reported at atmospheric pressures.

The data in Figure 5 show this acceleration in the basic pH range for oxygen pressures 115, 315, and 515 psia in 24-hour tests. The acceleration is very slight in the 115-psia system. These data show the importance of running corrosion tests for a sufficient length of time to simulate actual field tests. In order to more completely define the effect of time, tests should probably be run for at least 60 days' duration. In the test described above, there was some problem with maintaining constant pH throughout the test periods. This was especially true in the low pH range where large concentrations of iron are present. In all cases the pH tends to approach 9-10. In order to maintain the pH constant throughout the test run, it is necessary to have a relatively large volume of electrolyte (4 liters) and small surface area of corroding coupon (2.9 in.²). The effect of maintaining constant pH (±.1 pH unit) is illustrated by Figure 6. There is no great

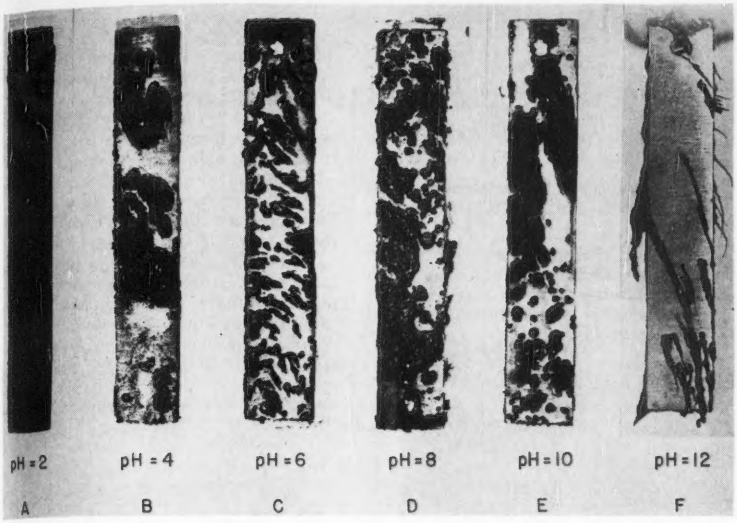

Figure 10—Comparison of corrosion product formation. System: 5 percent NaCl brine, 500 psi; oxygen, 24 hours exposure, with stirring.

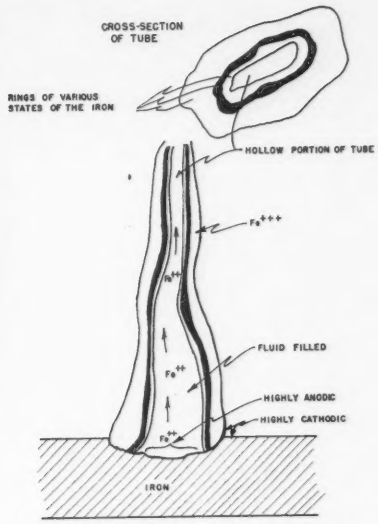

Figure 11—Corrosion tube growth mechanism.

change in general nature of the corrosion curve; however, in order to be more quantitative, all the subsequent data were determined with the pH at a constant value.

In Figure 7 some data were summarized showing the effect of pH and oxygen pressure on the corrosion rate of mild steel. Additional data obtained at 215, 315, and 415 psi fit into this same family of curves. These experiments were all carried out for only 6 hours. In all cases, the corrosion rate increased with increasing oxygen pressure. The pH required to eliminate oxygen corrosion increases with increasing oxygen pressures. At 515 psia, pH of about 13.5 is necessary to stop corrosion. It should be remembered that, if these tests were carried out for longer periods of time, the acceleration effect in the pH range 8-12 would be superimposed on these curves.

It is of interest to note in Figure 8 that, in a given pH system, increases of oxygen above 200 psi have little effect on corrosion rate (except at a pH of 2.) Another interesting feature is that the pH 4, 6, and 8 curves are identical.

All of the experiments described above were carried out in stirred systems. Further experiments in unstirred systems indicate that the accelerated corrosion phenomena in the pH range 8-12 did not occur. This fact is illustrated by the data in Figure 9.

Nature of Corrosion and Corrosion Product

This accelerated corrosion in the basic pH range seems to be associated with the nature of the corrosion and the corrosion product formed. The effect of pH on the nature of corrosion is well illustrated by the photographs of individual coupons as shown in Figure 10. At very low pH, corrosion rate is very uniform in nature. As pH is raised, the corrosion process becomes increasingly more localized. At very high pH levels, major portions of the coupon are unattacked. Extremely severe localized corrosion is evidenced in the form of filament or whisker growth at this pH. It was interesting to note that these filaments are actually hollow tubes whose cross-sectional dimensions vary from about 10 microns to 4 milimeters. The resultant pitting rate at the base of these filaments was shown to be as much as 0.2 centimeter in 4 days or 17,000 mpy. A proposed mechanism for the formation of this tubular corrosion product is described in Figure 11.

Corrosion nucleates at anodic areas and resultant ferrous hydroxide deposits on the periphery of the anodic spot as described in Figure 1. This is rapidly oxidized to various iron oxides. This further oxidation depletes the oxygen supply in the anolyte and contributes to sustaining the corrosion processes by maintaining a differential in oxygen concentration. As the tube grows, electrolyte must flow into the tip of the filament and toward the iron surface. The oxygen-depleted electrolyte reaches the surface which is highly anodic with respect to the large cathodic surface outside the filament. The electrolyte within the tube was sampled and its pH determined to be about 3.0. This is further evidence of the anodic nature of the interior of the tube. The entire mechanism is provided for by the corrosion reactions in the Introduction of this paper.

X-ray Identification

The tubular corrosion product of the 500 psi oxygen 12.0 pH system was identified by X-ray techniques. The oxygen corrosion process of iron in salt water as the anode causes the formation of iron chlorides and hydroxides. The abundant supply of oxygen (345-424 ppm) continues to oxidize these chemicals with the formation of more chlorides and hydroxides and conversion to other states of iron. The initial iron chloride being retained in solution was not detected by X-ray. The ferrous hydroxide gel was equally nondetectable by X-ray; however the tetrahydrate of ferrous chloride was positively detected as were lepidocrocite and maghemite, permitting the hypothetical sequence of iron states as shown at the bottom of this page.

Conclusions

1. The corrosion of mild steel due to oxygen and sodium chloride can be reduced to a minium by controlled high pH systems (the higher the oxygen concentration, the higher the pH of the system needs to be).

2. An unexpected accelerated corrosion occurs in the pH range of about 8-12. Extremely localized corrosion occurs on steel in systems of 12.0 pH at 3-500 psi.

3. A possible mechanism of the tubular corrosion product is proposed and considered to be a type of oxygen concentration cell.

4. The accelerated rate of corrosion in the tubular growth is due to the difference in oxygen concentration of cell (the anode being low in oxygen and the cathode being high in oxygen). In the highly basic systems where the extremely localized corrosion is observed, it is postulated that the tubular corrosion product maintains the oxygen differential between the anode and the cathode area.

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$$Fe(OH)_2 + FeCl_2 \text{ — } FeCl_2 \cdot 4H_2O \text{ — } \gamma HFeO_2 \text{ — } \gamma Fe_2O_3$$

Liquid — Ferrous Chloride Tetrahydrate — Hydrated gamma ferric oxide (lepidocrocite) — Ferric oxide anhydrous (maghemite)

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Question by Edgar C. Winegartner, Humble Oil & Refining Co., Baytown, Texas:

What is the effect of higher pH levels on oxygen solubility? Could changes in oxygen solubility due to increased pH account for some of the differences noted with 1N and saturated solutions?

Reply by O. L. Riggs, Jr.:

The higher pH levels tend to decrease the amount of oxygen which can be dissolved in a given amount of solution. The same fact is true of the lower pH levels.* The systems of intermediate pH values contain such an extremely small amount of NaOH or HCl, the oxygen solubility change was completely ignored (pH values approximately 4 to 10). However, the difference in data resulting from 1N solution and saturated solution cannot be attributed to oxygen solubility. It is believed the dominant factor which caused the reversal of data from 1N and saturated solution to be due to NaOH. The saturated NaOH solution reacts to the metal specimen by dissolving iron hydroxide film and etching metal surface, contributing to a more severely corrosive system than the 1N NaOH system.

* A. Seidell. Solubilities of Inorganic and Metal Organic Compounds, D. Van Nostrand Co., Inc., 3rd Ed., Vol. 1, p. 1355 (Geffcken, 1904).

Any discussion of this article not published above will appear in the December, 1960 issue.

Laboratory and Plant Applications of

Recording Electrical Resistance Corrosion Meters*

By E. C. WINEGARTNER

Abstract

The application to plant and laboratory corrosion studies of instruments which continuously record the thickness of corrosion test probes is discussed. A discussion of the instrument components involved and general precautions necessary to obtain meaningful results is included. Careful consideration of design features of the test probes is required in order that they be installed properly to obtain the type of information desired.

The use of the electrical resistance method for determining corrosion rates has been increasing rapidly during the past five years. Continuous recording of the results of such tests makes it possible to determine when corrosion occurs in order that additional studies can be made to show how it occurs. Several plant applications of the method are described which demonstrate the usefulness and reliability of the equipment. Laboratory tests which are described not only demonstrate the usefulness of the equipment for corrosion studies but also show that good indications of the presence and concentration of transient corrosive intermediates may be obtained. Such measurements have aided in identifying chemical reactions occurring in chemical processes being developed, and have influenced the process design of the commercial plants.

2.4.2

Introduction

THE ELECTRICAL resistance method for measuring the extent of corrosion of a metal utilizes the fact that metals and alloys have much lower specific electric resistances than their corrosion products. Since the electrical resistance of a metal depends on its cross-sectional area, the electrical resistance of a metal shape will increase as its cross-section is reduced by corrosion. It is thus possible to determine the cross-sectional area of a metal wire, strip, or tube by measuring its electrical resistance while the metal is being corroded without removing the metal probe from the corrosive environment or disturbing the metal surface.

A number of investigators[1-5] have used this principle for the solution of special problems in corrosion research. More recently the method has been developed and improved by Dravnieks et al[6,7,8]; equipment based on these developments[9] is now commercially available.

This method involves use of a special probe inserted in the corrosive environment. The electrical resistance of this probe rather than of the equipment itself is determined. The measurement is an indirect one, in that the resistance of an exposed element in the probe is compared with the resistance of a second element in the assembly which is protected from the environment. The difference between the electrical resistance of the two elements provides the basis for the measurement. Equipment for the periodic monitoring of probes both in the laboratory and in processing units has found rapid acceptance and is described elsewhere.[10-14]

The many advantages of instruments which continuously record the thickness of corrosion probes are not generally realized. It will be the author's purpose here to show how such instruments may be used to aid in the solution of corrosion problems.

Corrosion tests are usually undertaken either to determine which metals or alloys will resist a specific set of operating conditions, or to find out what can be done to change operating conditions so that less expensive metals can be used. The exposure of coupons and their subsequent evaluation by visual examination and determination of weight loss provides an excellent method for determining the best alloy to use under specific operating conditions. When weight loss measurements are used to study the effects of changes in operating conditions, only average corrosion rates over the periods of the tests are obtained. It is not known whether the corrosion was uniform throughout the period of the test or occurred during only a small portion of the test period. If attempts are made to shorten the period of exposure in order to obtain more detailed information, then errors due to experimental techniques such as cleaning become very important. The electrical resistance technique is extremely sensitive and appears to be ideally suited for this type of testing.

Several papers dealing with the use of this method for the evaluation of corrosion inhibitors in service are available in the literature.[16-19] Since no cleaning or handling of the specimens is required, tests may be conducted for as short a period of time as desired, and continuing tests with the same specimen may be made. The further development of this technique resulted in the continuous plotting of metal thickness versus time so that, in effect, the instrument becomes an electronic magnifying glass which amplifies changes in metal thickness about one million times and records the changes on a chart for detailed study.

About the Author

E. C. WINEGARTNER is a Senior Research Engineer with the Humble Oil & Refining Company at their Baytown, Texas refinery. After receiving a BS in Metallurgical Engineering from Ohio State University in 1949 he was employed by the Brush Beryllium Company at Lucky, Ohio. In 1951 he was employed by Humble in the Metallurgical Laboratory of the Maintenance Engineering Department. In 1954 he transferred to the Corrosion Group of the Research and Development Division where he is presently employed. His duties include mitigation of corrosion in plant equipment, selection of materials for processes under study, and investigation of long range corrosion and materials problems.

Description of Equipment and Procedures

Measuring and Recording Equipment

An example of the measuring equipment used in the author's work is shown in Figure 1. The principle of operation of this equipment is given in Appendix 1. There are four basic components to the equipment which are identified by number in Figure 1 and described briefly below.

Voltage Regulating Device. It has been found desirable to use a constant voltage transformer of the electronic type to regulate the power supply to the instrument. The instrument will operate fairly satisfactorily without it, but more reliable results are obtained, especially for field use, if voltage fluctuations are eliminated. Saturable core transformer voltage regulators give some improvement but an electronic type is more satisfactory in this service. The voltage regulator should have an effective magnetic shield or be located at some distance from the instrument proper to avoid difficulties from stray magnetic fields.

Measuring Unit. The measuring unit contains a potentiometric bridge-circuit for measuring the ratio between the resistances of the exposed and reference specimens in the probe. A precision potentiometer, driven by a mechanical link from the servo unit, controls the corrosion totalizer dials and the electrical output to the recorder. The transmitting potentiometer automatically resets every nine units so that the information is well spread out on the recorder chart.

Servo Unit. The servo unit receives the imbalance signal from the bridge-circuit in the measuring unit. The amplified signal is used to power a servo motor that drives, through a mechanical link, the bridge potentiometer in the measuring

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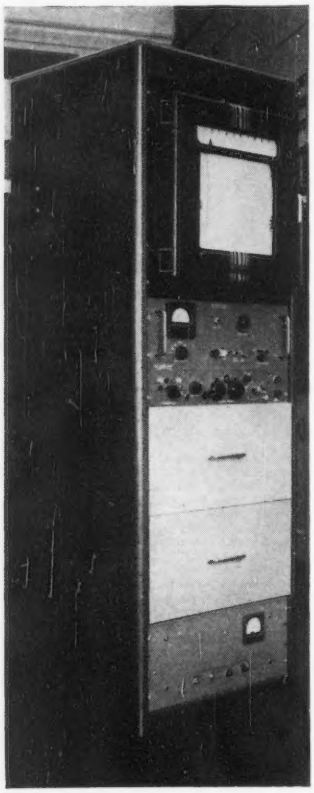

Figure 1—Recording electrical resistance corrosion meter. Code to numbers is as follows: (1) Voltage regulation device, (2) Measuring unit, (3) Servo unit, (4) Millivolt recorder.

unit. The servo unit also contains the power supply for the probe circuit.

Recorder. Almost any millivolt recorder may be used since the output from the measuring unit may be varied from 0-5 mv to 0-100 mv full scale by changing an easily accessible resistor. For laboratory use the author chose a 0-50 mv, multiple point, strip chart recorder with a 9½ inch scale and 2 inch per hour chart speed in order to obtain suitable magnification of results and to provide a scale suitable for plotting thermocouple temperatures as well as corrosion results. For a separate unit used primarily in the field, a 0-50 mv circle chart single point recorder was chosen in order to have the maximum amount of information visible and to have as great a distance as possible (4½ inches) from zero to full scale.

A programming unit is also available to time-share a single servo unit and multiple point recorder among two to twelve measuring units. An internal clock automatically sequences the measuring units at a rate of approximately one per minute so that one complete unit can monitor as many as 12 probes.

Description of Probes

A wide variety of probes are available from the supplier of the instrument. A brief description of their principle is given in Appendix 1 and a more complete description of commercial probes is given by Rohrback.[14] It is also possible to prepare probes in the laboratory.[6,12] The author has found the commercial probes to be good, but not perfect. Difficulties due to misapplication of probes or to probe defects show up immediately when using the recording meter in the form of erratic readings or a wavy line.

It has been stated[14] that the type probe commercially available, in which the resistance of the exposed element is compared to the resistance of a coated reference element, is self-compensating with respect to temperature. This is not completely correct since the temperature of the two elements is a function not only of the temperature of the test solution, but also of the rate at which the probe is able to dissipate the small amount of heat generated by the current passing through the probe. Since the coating on the reference element interferes with the conduction of heat away from this element, the two wires are seldom at exactly the same temperature. Under static temperature conditions a constant temperature difference is arrived at and automatic temperature compensation is achieved. After a large shift of temperature of the medium has occurred, the rates of heat transfer from the exposed and coated elements are both altered, and a new Δt is established.

Other variables, such as mechanical stress which affect the resistance of the metal elements, may change appreciably with temperature. The net result is that the absolute reading from the corrosion meter may show a major shift with a large shift of temperature. Once equilibrium is again achieved, the slope of the metal loss versus time curve will line out to give accurate corrosion rates even though this curve may be displaced from its position prior to the temperature change.

The effect of reduced heat dissipation from the coated element on temperature compensation in a liquid system is usually small and depends largely on the type of coating used. The author also has found that the rate of heat removal from the two elements will vary with the environment. The rate of heat dissipation from the metal and from the coating surface will be different in hydrocarbon, water, and gas. Under constant conditions, the Δt will become constant. If the probe is alternately wetted with hydrocarbon and water or with hydrocarbon and gas, fairly large changes will occur in the absolute readings. With a recording instrument such changes are no problem if they do not occur too rapidly. Indeed, it is possible to measure the corrosion rate separately in each phase. When taking periodic readings with a portable instrument, such changes would result in a scatter of the data which cannot be satisfactorily interpreted.

Variations in probe current are another source of changes in the absolute reading of the instrument. Heat input is proportional to the square of the current and therefore in those cases where differential heat dissipation is a problem, effects of changing probe current are multiplied. In addition, some alloys do not conform exactly to Ohm's Law, in that the effective resistance varies slightly with current. The instrument is sensitive enough to show these variations. The effect of changing probe current is one of the major reasons that necessitate accurate voltage regulation.

Stress induced changes in electrical resistance also have been observed with corrosion test probes. Such changes generally result in fluctuations of ±2 instrument divisions. These stresses are usually the result of exposing the probe to severe turbulence without proper shielding. Stresses may also be induced in the reference element by mechanical restraint due to differences in coefficient of thermal expansion between the metal and the coating material. Good shielding or installation of probes in specially designed bypasses will minimize such problems.

Setup of Equipment

The first rule in setting up a test with a recording electrical resistance type corrosion measuring instrument is to get the probe in the right place. Points of high turbulence should be avoided if possible. The instrument will accurately measure the corrosion rate of the exposed wire only. If corrosion is more pronounced in a condensing film it may not be possible to exactly reproduce these conditions on the probe. For this purpose a probe located in a water drawoff or in a bypass line some distance away may be more satisfactory than one located at the point of highest attack.

The instrument is then set up at some convenient location. The author generally uses the unit control room. The commercial instrument is not explosion proof; however, most of the other instruments in the control houses are also not explosion proof. Whether used in the field or in the laboratory the instrument must be completely grounded using No. 10 wire to a good mechanical ground. All components should be firmly grounded to the case and the case attached to the mechanical ground.

Since the instrument operates on the Kelvin Bridge principle and separate current and potential leads are used, IR drop in the potential leads is of no consequence and the distance from the probe to the instrument may be fairly large. The author has used 200 foot leads with no difficulties. If the distance becomes much greater than this, larger current leads or increased voltage will be required to overcome IR drop through the current carrying conductors. Leads available from the instrument manufacturer are especially constructed to avoid "cross talk" and have proved satisfactory for field use. Leads used in the laboratory have been shielded with a braided steel cover to void interference from stray electrical and magnetic fields. No difficulties have been experienced from this source in the field despite the proximity of large induction motors

In laboratory tests at temperatures above ambient, probes have been installed in flasks heated by electrical resistance heaters and stirred with Teflon covered magnetic stirrers. The stirrer is necessary to maintain constant temperature condi-

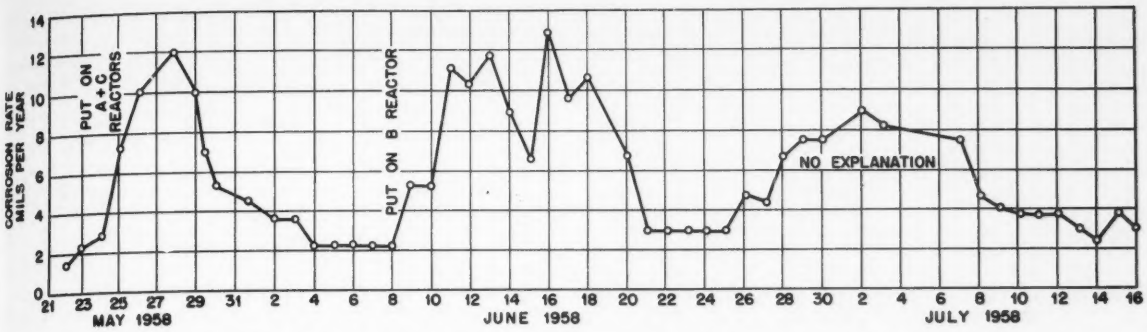

Figure 2—Corrosion rate of electrical resistance probe in water phase from catalytic polymerization unit reactor product condenser.

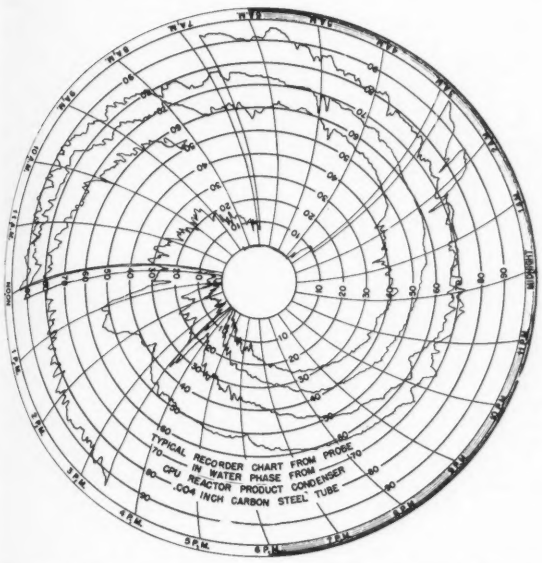

Figure 3—Typical recorder chart from probe in water phase from CPU reactor product condenser (0.004 inch carbon steel tube).

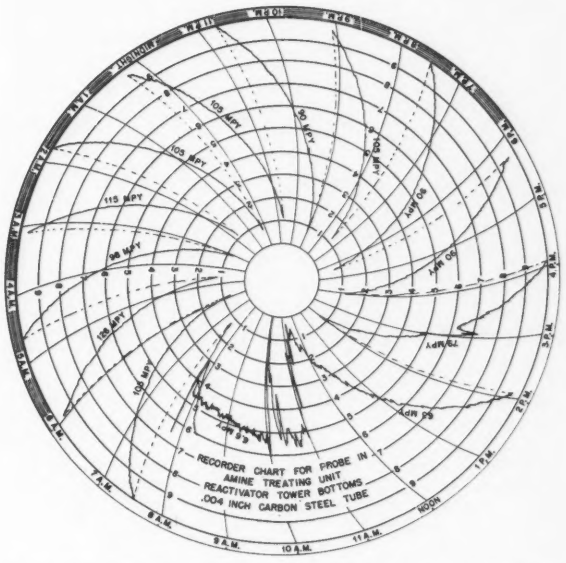

Figure 4—Recorder chart for probe in amine treating unit reactivator tower bottoms (.004 inch carbon steel tube).

tions in the flask and to remove heat from the probe specimen. No difficulties have been experienced attributable to this rotating magnetic field. The stirrer is carefully grounded, and a grounded aluminum shield is placed between the flask and the heater and stirrer to eliminate stray currents. The resistance heater is controlled by a variable transformer supplied from a voltage regulating device, thus avoiding on-off control and consequent temperature fluctuations.

Applications

Catalytic Polymerization Unit

The first application of this equipment to a plant problem was made at a unit in which propylene is polymerized to higher boiling products with the aid of an acid catalyst on a solid support. If any of the catalyst is carried from the reactors and allowed to enter the fractionating equipment, strong acid will be formed where water condenses. It was desired to know if and when such catalyst carryover occurs. To accomplish this, a small bypass was installed downstream of the reactor product condensers in such a manner that it served as a water separator. An electrical resistance corrosion probe was installed in the water phase in this bypass and monitored with the recording meter.

Corrosion rates obtained with this instrument during the first two months of its operation are plotted in Figure 2. It will be seen that the base corrosion rate appears to be between 2 and 3 mils per year. During periods immediately following the bringing-on of a fresh reactor, the corrosion rate increases to 10 to 12 mils per year for a period of about two weeks.

During one two-week period from late June to early July, corrosion rates increased to 8 mils per year with no apparent reason. It was found that when catalyst carryover occurred from the reactors such as when a new reactor is being brought-on, the corrosion rates increase gradually rather than abruptly, and stay at a higher level for several days before tapering back down to normal rates. It is believed that this is due to catalyst lodging in the product condensers and then gradually passing out into the system as water becomes available to form acid. This results in less severe corrosion but spread out over a longer period of time. It is apparent that corrosion coupon exposures would not give a very good picture of what was taking place under these conditions.

Figure 3 is a copy of a typical control chart from the unit. Each major division on this chart represents two millionths of an inch lost from the probe. The pen automatically resets to approximately zero after every 18 micro-inches lost. The average corrosion rate on this chart is about 7.5 MPY. Data from four days operation are shown here. The small fluctuations in the line are due to changes in line voltage at the unit. It is of interest to note that some of these fluctuations occur at the same time each day, such as between 3 and 4 PM when mechanical personnel quit work. As a matter of interest, it is also possible to determine the time of sunrise from this chart since there is a voltage fluctuation at about 5 AM each day when the lights at the

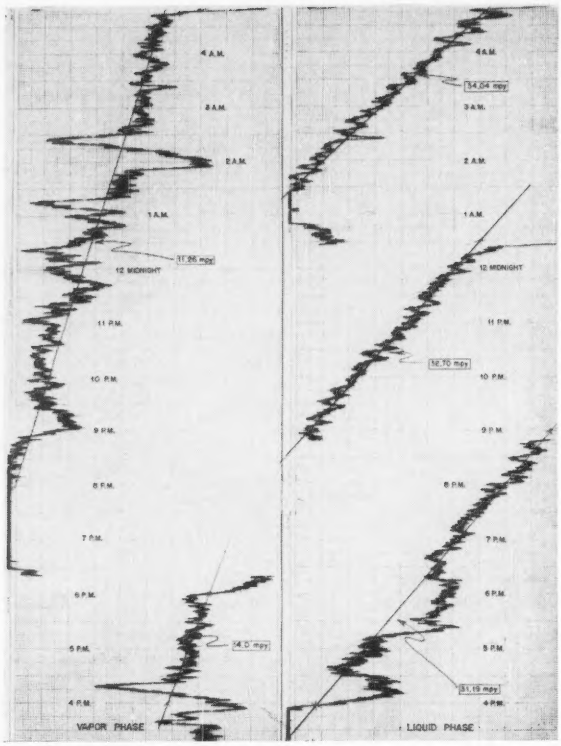

Figure 5—Recorder chart for probe in phenol evaporator tower (0.004 inch carbon steel tube).

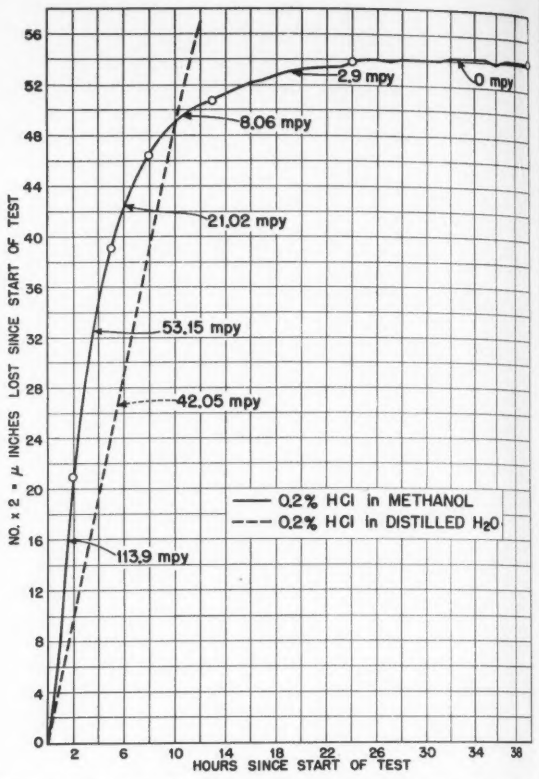

Figure 6—Metal loss data from Monel probe in 0.2 percent HCl-methanol and 0.2 percent HCl-water solutions.

units are turned off. Because of these fluctuations a voltage regulator was installed ahead of the instrument in subsequent installations. The chart indicates metal thickness only. In order to obtain corrosion rates one must obtain from the chart the amount of metal loss over some interval of time and convert to a standard time interval. For example, if the chart indicates that two millionths of an inch was lost in one hour, then multiplying this number by 8,760 hours per year would give a corrosion rate of 0.0175 inch per year. It will be observed that the corrosion rate during the period of time covered by the chart in Figure 3 was fairly constant since the slopes of the lines are obviously very similar.

Amine Scrubbing of Gas from Catalytic Cracking

In the amine treating of catalytic cracking plant gases for removal of H_2S and CO_2, strong organic acids such as acetic and formic acid build up in the circulating amine and may cause corrosion of regeneration facilities. It has been found that addition of caustic to the amine[15] ties up these acids as their sodium salts thus preventing corrosion and allowing more efficient use of the amine. Unfortunately, no routine analytical procedure has been developed to tell the operators how much caustic to add or when to add it.

In order to provide a control criterion for caustic addition, a corrosion probe was installed in a small bypass line from the bottom of the reactivator tower to the outlet of the first lean amine cooler. The instrument chart in Figure 4 shows what happens when caustic addition rate is not sufficient to neutralize the incoming strong acids. Between 8 AM and 10 AM sufficient caustic was present to neutralize the acids. Between 10 AM and 11:30 AM changes were made which resulted in a deficiency of caustic. During the next eight hours the corrosion rate rapidly increased to over 100 MPY. Since the exact time of the upset is shown by the chart, it is now possible to check other instruments at the unit and determine what happened to cause the increase in corrosion rate. Once the causes for such upsets are determined the operators at the unit can be properly instructed to watch the instrument and take appropriate action when corrosion rates increase.

Phenol Evaporator Tower

The corrosion rate of carbon steel in the bottom section of a fractionating tower in which phenol is separated from a heavy aromatic hydrocarbon extract was determined with the recording meter. Temperatures at the location under investigation were about 500 F. The only location available for a probe was through a valve on the side of the tower. A retractable probe was inserted through this valve at a point thought to be slightly above the liquid level in the tower. A portion of the instrument chart is shown in Figure 5.

It is apparent that despite the adverse conditions brought about by severe turbulence and temperature fluctuations, meaningful data were obtained. It was found that the liquid level fluctuated in the tower and data for both liquid and vapor phase corrosion rates were obtained. The vapor phase rate was about 12 MPY while the liquid phase rate was about 34 MPY. It was not possible to obtain data on the effect of firing rate since changing the rate of heat input changed the liquid level and conditions at the unit prevented prolonged testing. Under these adverse conditions it would have been very difficult to obtain meaningful data from coupon exposure or from corrosion probes which require intermittent reading with a portable meter.

Laboratory Tests in HCl and Anhydrous Methanol

The effect of anhydrous HCl-methanol mixtures on the corrosion rate of Monel was determined during a laboratory investigation. Methanol used in these tests was dried with magnesium methylate and analyzed less than 25 ppm water. The anhydrous HCl was dried by passage through P_2O_5. The test probe was set up in a flask inside of a dry box purged with Seaford grade nitrogen. The data for one run in which 0.2 wt. percent HCl was added to methanol are shown as a solid line in Figure 6. The broken line in this

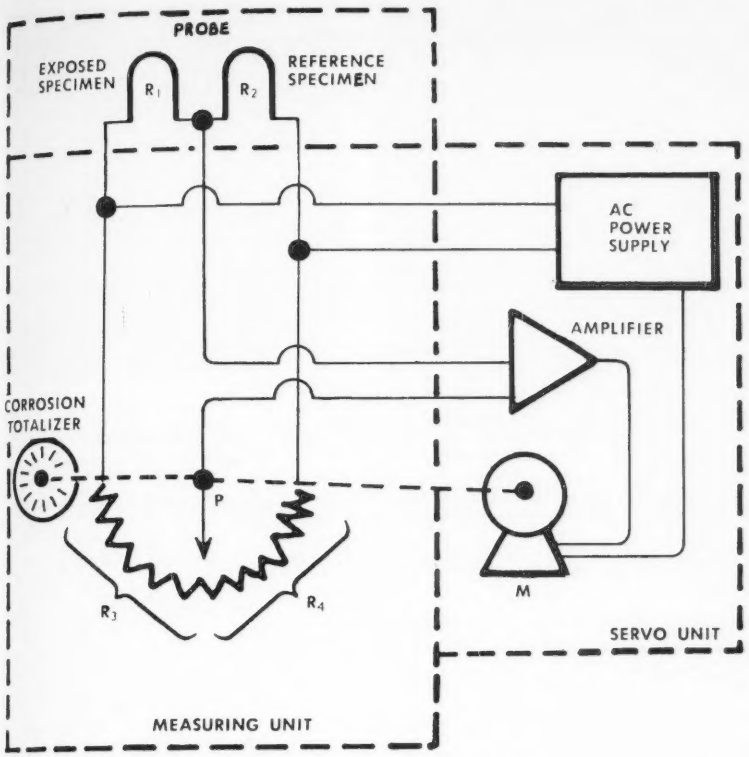

Figure 7—Electrical resistance corrosion meter circuit.

figure represents data for the same concentration of HCl in water. It will be observed that the initial corrosion rate of Monel in the HCl-methanol solution was much higher than for HCl-water solutions but that the rate dropped off rapidly and became nil after about 24 hours. This type of curve is not unusual when a protective film is formed on the metal surface; however, in this case no such film was possible. Further investigation showed that the rapid decrease in corrosion rate was due to a decrease in HCl concentration brought about by the reaction

$$HCl + CH_3OH \rightarrow CH_3Cl + H_2O$$

in which the methyl chloride formed was not corrosive. Because of the initial dryness of the system this reaction was found to proceed much more rapidly in the system under investigation than would be suspected from literature data. In a system such as this, where one of the reactants or intermediates is corrosive, it is possible with further refinements to use corrosion rates measured continuously to measure the rates of reaction of the primary constituents in the system or to determine at any given time the concentration of a corrosive intermediate. As a result of the experiments described above, several changes were made in a system under study which resulted in a less corrosive process.

Conclusions

The application of recording electrical resistance corrosion meters to both laboratory and plant problems has provided valuable information regarding how and when corrosion occurs. In plant applications they have been found to be especially valuable in determining exactly when corrosion takes place so that changes in operating procedures which will minimize corrosion can be investigated directly. The author makes no claims regarding the exact correlation between the corrosion rate of the probe and the corrosion rate of the equipment in which it is installed. The rate of metal loss from the probe is accurately measured, however, and it is up to the corrosion engineer to design his experiment so that the most useful type of information is obtained. This is not necessarily actual metal loss from the equipment, but rather may simply be the effect of operating conditions on the corrosivity of the system.

In laboratory corrosion tests the use of the recording meter permits evaluation of factors not readily apparent in routine coupon testing. The technique supplements rather than replacing coupon testing and makes the results of coupon testing more meaningful. Under certain conditions the recording corrosion meter can provide valuable information on rates of reaction and on the concentration of reactants.

The recording electrical resistance corrosion meter does not replace the corrosion engineer; it just makes his life more complicated. Since more factors can be evaluated more rapidly there is a greater need than ever for good experimental design and qualified interpretation of results. This tool gives the corrosion engineer additional help in finding out "why" rather than simply "how much" corrosion occurs.

Acknowledgments

The author expresses his appreciation to the Humble Oil & Refining Company for permission to publish this paper, and to the Crest Instrument Company for their help in developing the techniques and for permission to include their discussion of the instruments in this paper. The help of L. A. Robertson in conducting the experiments described herein is gratefully acknowledged.

APPENDIX 1—Principle of Operation of Recording Electrical Resistance Corrosion Meter*

The recording electrical resistance corrosion meter employed in this work measures corrosion on metallic alloys by determining changes in the resistance ratio of an exposed specimen, exposed to a corrosive medium, and a reference specimen of the same metal protected by a coating. As corrosion proceeds, the electrical resistance of the test specimen increases, and this change is measured by the "bridge" circuit shown in Figure 7. The wiper of the precision potentiometer, P, is driven by the servomotor, M. When the potentiometer resistances R_3 and R_4 have exactly the same ratio as that of R_1 and R_2, the bridge is in balance, and no current flows through the motor windings. When corrosion changes the value of R, however, an imbalance occurs, causing the motor to turn until the potentiometer again is set at a balanced position. Rotation of the potentiometer shaft is therefore a direct measure of the progress of corrosion. This shaft rotation is used to drive the individual corrosion totalizer dials and to produce an electrical signal for the recorder.

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* This information was obtained from, and is presented with the permission of, the Crest Instrument Company, Santa Fe Springs, California.

DISCUSSIONS

Question by Andrew Dravnieks, Standard Oil Co. (Indiana), Whiting, Indiana: What was the order of magnitude of difference in readings on the same probe when the "electrical cross section" was measured in hydrocarbon and water?

Reply by E. C. Winegartner:

When a carbon steel corrosion probe was measured first in deaerated distilled water and then in a kerosene boiling range hydrocarbon at the same temperature in the laboratory, a difference in reading on the instrument of 4 units or 8 microinches was obtained. The reading in the water was less than the reading in the hydrocarbon.

Questions by N. L. Conger, Continental Oil Co., Ponca City, Oklahoma:

1. Were any correlations made between corrosion rates indicated by the corrosion meter and actual corrosion within the system?

2. What were the magnitudes of current flow through the corrosion meter probe?

Reply by E. C. Winegartner:

1. Correlations of this nature have been made on several occasions. It has been found that when corrosion test coupons are installed close to the corrosion probes and precautions taken to make sure that they are exposed under identical conditions, the corrosion rates obtained are very close. In one test, a corrosion rate measured over a period of 30 days with a ½-inch x 3-inch x 1/16-inch carbon steel coupon was found to be 4.5 mpy. The average corrosion rate obtained with the corrosion meter was 4.9 mpy. In the more general case duplicate tests are not made since it is the author's opinion that the electrical resistance corrosion meter is best suited to determining when corrosion occurs in order that processing conditions may be controlled to eliminate corrosion and that coupon exposures provide a more satisfactory method for determining long term corrosion rates. The two methods complement each other and are not necessarily required to check one another.

2. The current flow through the corrosion meter probe was approximately 0.25 ampere with the probes used by the author. This resulted in a heat release of approximately 0.4 BTU's per hour from the probe.

Questions by A. J. Freedman, Nalco Chemical Co., Chicago, Illinois: Is your voltage regulator used to regulate the power supply to the electronic equipment or just the current supply to the probe?

Reply by E. C. Winegartner:

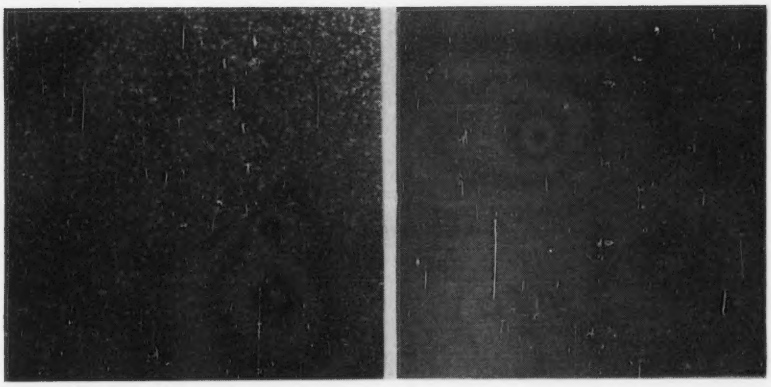
The voltage regulator is used to regulate the power supply to all of the electronic equipment, not just the current supply to the probe.

Any discussion of this article not published above will appear in the December, 1960 issue.

NACE Guide for Preparation of Articles for Publication

Persons interested in submitting articles on corrosion for publication in CORROSION can obtain upon request a copy of the "NACE Guide for Preparation of Papers." Write to CORROSION, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

Figure 1—Severely etched surface of a 430 stainless steel which had been in atmospheric service less than three months during the winter of 1958-1959.



A B

Figure 2—Samples of the same steel exposed on the same outdoor test rack for one month. Sample (A) was exposed during March 1959, sample (B) during May 1959.

Effect of Chromium Depleted Surface On Corrosion Behavior of Type 430 Stainless Steel*

By R. V. TRAX and J. C. HOLZWARTH

Abstract

Loss of chromium during steel mill processing is discussed together with the effect of this chromium depleted surface on atmospheric corrosion. A bench test for rapidly identifying the presence of chromium depleted surface is described and correlated with outdoor exposure tests. From laboratory studies cited several methods of overcoming this chromium depleted condition in Type 430 stainless steel are apparent. These methods include the use of a longer annealing cycle, a more complete pickling treatment after each high speed anneal, and mechanical abrasion of the surface. 8.8.5

Introduction

CORROSION PROCESSES generally occur only at surfaces. Therefore, a corrosion resistant alloy should, by definition, present to the environment a chemically inert surface. It may do so through intrinsically unique electronic configuration of the metal atoms as in the case of platinum or gold[1] or by forming, naturally or artificially, a thin passive film as in the case of stainless steel.

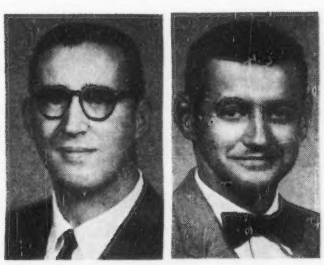
It is well known that stainless steel derives its resistance to corrosion from the presence of chromium. It is also generally agreed that the degree of passivity attainable is a direct function of chromium content and that a high order of rust resistance in most oxidizing environments is afforded when the chromium content reaches about 16-18 percent, whereas a marked decrease in resistance to atmospheric attack is realized below 12 percent chromium.

The corrosion resisting ferritic iron-chromium steels exemplified by Type 430 (16 percent chromium), are often supplied by the steel mills in the form of flat rolled product having a high degree of surface finish. They are often fabricated and used with relatively little additional surface preparation.

Recently this type of stainless steel has been observed to corrode unexpectedly within a few weeks of exposure in industrial and coastal areas. In these same areas, many lots of steel of the same apparent chemical composition have been in service for 20 years with no evidence of corrosion. This also has been observed by Larrabee.[2] The rate of attack recently observed suggested that the chromium content was considerably below the nominal 16 percent specified for this type material, even though conventional chemical analysis of the steel showed it to contain the specified level of chromium.

This paper deals with a study of surface depletion of Type 430 stainless steel in chromium, its cause, its effect, and a rapid test for its detection.

★Submitted for publication December 4, 1959.



Trax Holzwarth

R. V. TRAX is a metallurgical engineer at the General Motors Research Laboratories, Warren, Michigan, where he is engaged in research on the corrosion resistance of metals. He received a BS in 1957 and an MS in 1958 from the Michigan College of Mining and Technology.

J. C. HOLZWARTH is Assistant Head, Metallurgical Engineering Department, General Motors Research Laboratories. He received his BS and MS degrees in metallurgical engineering from Purdue University. Since joining General Motors in 1948, he has been active in studies of the metallurgical aspects of corrosion and the development of metallic protective coatings. He is a member of NACE and ASM.

Effect of Chromium Depletion on Corrosion Behavior

The rapid atmospheric deterioration observed for this type of steel is characterized partly by the formation of rust streaks but predominantly by severe shallow etching of the surface in spots or patches. This results in a somewhat superficial but permanently defaced surface as shown in Figure 1.

A number of test panels obtained from several different mill sources were exposed on outdoor test racks at various time intervals throughout the first half of 1959. The test site was the roof of an eleven story office building in midtown Detroit centering in a heavily industrial area.

It was found that this environment during the winter months (January-March) produced very rapid deterioration of the originally bright surface as shown in Figure 2A. On replicate samples of the same steels exposed during the warmer weather months (May-July), essentially no corrosion has occurred as shown in Figure 2B. From this it appears that accumulation of acid products from industrial wastes in the atmospheres during the winter accelerated the rate of attack whereas the heat and humidity present during the warmer months was insufficient to break down the mildly passive surface film.

Degree of Chromium Depletion

Conventional methods of analysis for chromium (i.e., spectrographic, X-ray

fluorescence, titration of a dissolved sample), failed to show differences in surface chromium content between corrosion resistant and corrosion-susceptible material. This came about because of the deep penetration into the base metal. Therefore, a method was devised for dissolving away thin surface layers from the sheet for quantitative analysis. This procedure was carried out in the following manner:

In a narrow paraffin vessel, increments of surface metal were pickled off corrosion susceptible Type 430 stainless steel panels using a 12 percent HNO_3-1 percent HF solution. The first increment was dissolved by 10 seconds immersion in the acid, subsequent layers by 20 seconds of immersion. The pickled surfaces were repeatedly rinsed with distilled water and rubbed with a rubber tipped stirring rod to permit collection of all of the solute from each increment of surface. Samples were weighed before and after each pickling operation and the thickness of metal removed was calculated from the weight loss/area/density relationship. Depth of pickling was further checked with a Profilometer which confirmed the calculated depth of metal removed. The pickling solutions were then quantitatively analyzed for chromium and iron. It was found that the total weight of chromium and iron in the solutions approached very closely the weight of metal removed. Generally five such increments were sufficient to show a substantial gradient of chromium concentration at the surface.

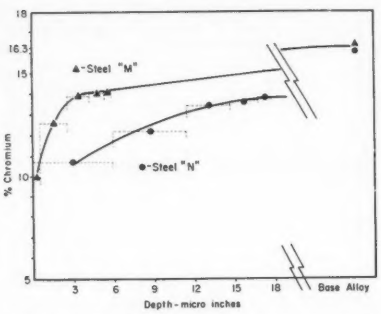


Figure 3—Chrominum content as a function of depth below the surface for two etch-susceptible steels. The more etch-susceptible material is depleted in chromium to a much greater depth. The plotted points represent the average chromium content of each increment of metal removed as shown by the dotted lines.

Results of surface analysis of two steels are shown in Figure 3. It can be seen that one of the steels (Steel "M") had a mean chromium content of 10 percent in the first half microinch increment below the surface. The second steel (Steel "N") showed an average chromium content of 10.7 percent in the first six microinches of surface. Extrapolation of these two curves to the surface would indicate that the surface chromium was no more than 9 percent in both steels. In one case the chromium deficiency was restricted to a relatively thin surface layer whereas the other steel showed depletion to a significantly greater depth. It was also apparent that the rate of metal removal decreased as the percent chromium increased. The base chemistry of these two steels was 16.3 percent chromium.

While the depth of chromium depletion was found to vary considerably from one lot of steel to the next, stainless steel having the bright mill finish covered in this study appears to be almost universally characterized by such surface deficiency. Indeed, of 56 lots of material obtained from eight different stainless mills, all but one lot showed evidence of such chromium depletion.

It was the opinion of the authors that:

1. The high speed annealing treatment of the cold reduced strip causes selective oxidation of the surface chromium.

2. This chromium rich oxide layer is then removed during bright pickling of the strip leaving a corrosion susceptible layer of chromium depleted surface metal.

Spot Test for Identification of Chromium Depletion

Because of the length of time required to obtain results on outdoor exposure and the seasonal variability of the atmosphere, it was highly advantageous to have a simple, rapid test for identifying the presence of the chromium depleted surface layer. Such a test was developed to:

1. Determine the cause of chromium depletion.
2. Apply corrective measures.
3. Control quality of mill product.

This test consists of a short time exposure of the Type 430 stainless steel

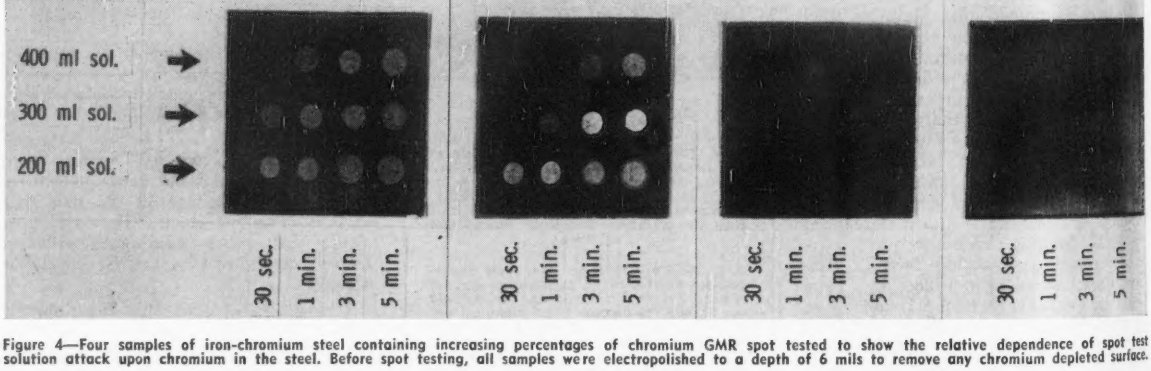


Figure 4—Four samples of iron-chromium steel containing increasing percentages of chromium GMR spot tested to show the relative dependence of spot test solution attack upon chromium in the steel. Before spot testing, all samples were electropolished to a depth of 6 mils to remove any chromium depleted surface.

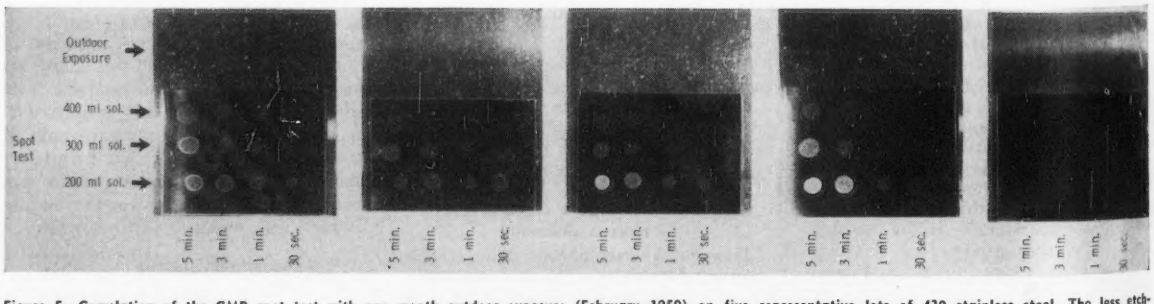


Figure 5—Correlation of the GMR spot test with one month outdoor exposure (February 1959) on five representative lots of 430 stainless steel. The less etch-susceptible materials show fewer spots after test.

surface to a sodium ferric chloride solution made by dissolving

10 grams	Ferric Chloride ($FeCl_3$—6 H_2O)
5 grams	Sodium Chloride
2½ ml	Concentrated Hydrochloric Acid

in 200 milliliters of distilled water. A drop of this solution in contact with the surface for five minutes has been observed to cause etching of 430 stainless steel which has less than about 14 percent chromium at the surface as shown in Figure 4. Evaluation is made by visual comparison of the original surface with the tested area after the solution has been removed. The intensity of the etched spot is a measure of the degree of chromium depletion.

Greater dilution of the solution with distilled water will cause a corresponding decrease in the intensity of the etch spot for a particular surface chromium content. In this paper, concentration of the spot test solution is identified by referring to the amount of distilled water added to the basic ingredients of ferric chloride, sodium chloride, and hydrochloric acid. The results of a concentration-time series of spot tests may be seen in Figure 5 along with outdoor exposure results on the same lots of steel.

Cause of Chromium Depletion

Since the rapid rate of surface deterioration observed for Type 430 stainless steel has been limited to bright finish mill stock, the loss of chromium appeared to be associated with some variable in mill finishing of the bright surface. A study of annealing and pickling treatments was conducted in the laboratory in which it was attempted to duplicate as much as possible present mill practices.

To understand the mechanism of chromium depletion, familiarity with present day continuous mill processing of bright finished stainless steel is necessary. While different mills use many different variations, a typical procedure is described as follows:

The ingot is soaked at 2200-2350 F in an oxidizing atmosphere. There is evidence that considerable chromium may be lost in this operation through volatilization and oxidation as pointed out by Caplan and Cohen.[3] Depth of depletion will depend upon time, temperature, and oxidizing potential of the atmosphere. After hot rolling, the slab is usually machined or scarfed to remove defects. The slab is then reheated, rolled to a thinner gage, and coiled.

The coiled hot band is then box annealed in the temperature range of 1350-1550 F for about 24 hours. Next it is pickled or blasted to remove scale, then cold reduced about 50 percent. At this point the strip is annealed at 1350-1600 F in a high-speed continuous furnace where the strip is at temperature for only a few minutes. Invariably the atmosphere is oxidizing to chromium. This treatment forms a thin oxide, usually deep blue in color, on the surface of the strip. The strip then passes into a continuous pickling bath (chemical or electrolytic) for the purpose of removing only the oxide, leaving the base metal unattacked and, therefore, bright and reflective. The strip is then cold reduced further to final gage, the high-speed annealing and bright pickling treatments being repeated. The final step is generally a temper pass on brightly polished planishing rolls.

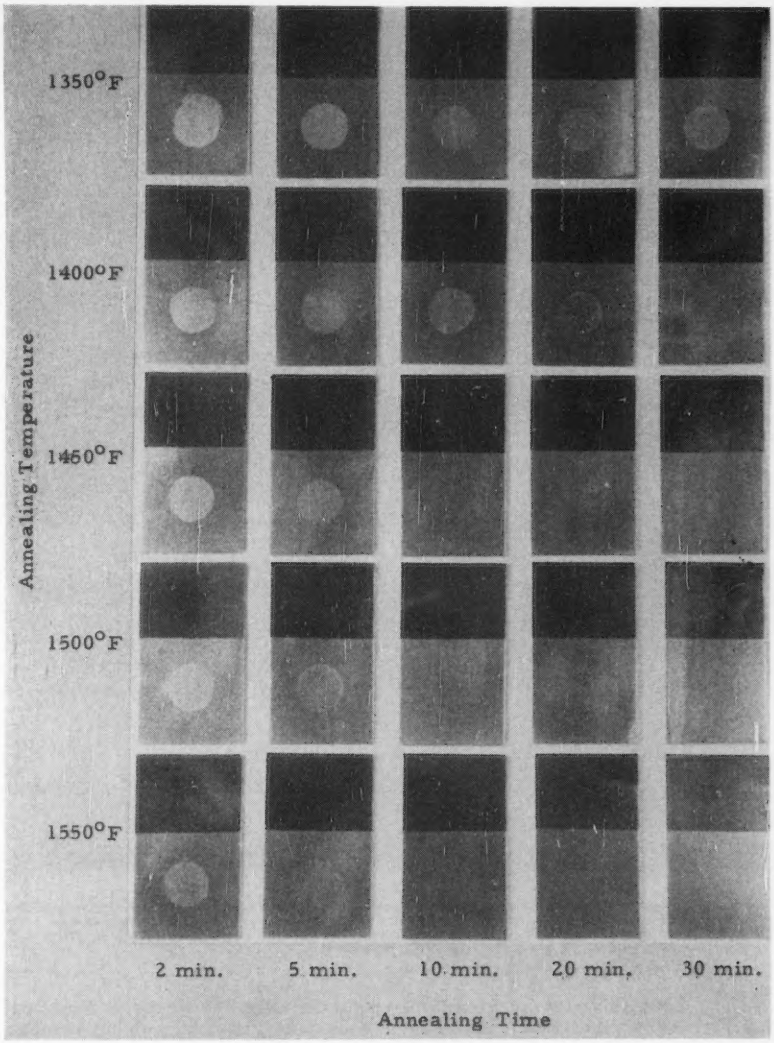


Figure 6—Annealing time vs temperature showing the appearance of etch-susceptible surface upon low temperature-short time annealing.

Effect of Pickling

It was found that:

1. Anodic treatment in 4 percent HNO_3 effectively removes the blue oxide formed during annealing, leaving the chromium depleted metal surface unattacked.

2. Anodic treatment in 5 percent sulfuric acid effectively removes both the oxide and the chromium depleted layer when the proper combination of current density and time is used.

3. A 12 percent HNO_3-1 percent HF acid solution effectively removes both the oxide and the chromium depleted layer when the treatment is of sufficient duration and the concentration of acid is closely controlled.

Effect of Annealing

Samples from one lot of Type 430 stainless which were initially etch resistant to the spot test were annealed at various temperatures and times in air. The bottom half of each panel was then anodically bright pickled in 4 percent HNO_3 to remove only the colored oxide prior to spot testing. It can be seen in Figure 6 that short annealing times and lower annealing temperatures produced an etch susceptible (chromium depleted) surface. However, the degree of etching does not appear to be as great as that found on commercial material.

Since it is known that the stainless strip generally received at least two annealing—bright pickling treatments, additional samples were given a series of short time anneals, each anneal being followed by bright pickling of the surface. The effect on chromium depletion was measured by the spot test. As shown in Figure 7, the repetitive treatments do have a cumulative effect in promoting progressive loss of surface chromium.

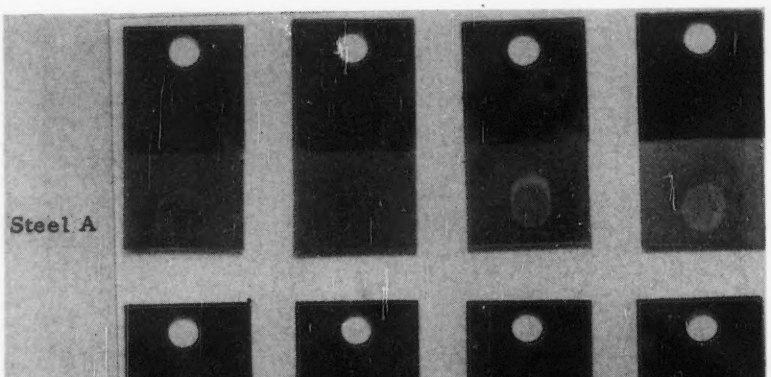


Figure 7—Cumulative effect of successive annealing—bright pickling treatments. Each treatment consisted of two minutes at 1450 F in air followed by anodic pickling in 4 percent HNO_3 to remove colored oxide from the lower half of the panel. Increasing severity of GMR Spot Test solution attack is shown with repetitive treatments.

The colored oxide formed by annealing Type 430 stainless steel for two minutes at 1450 F in air was carefully removed from the annealed stock and quantitatively analyzed for chromium. The stripping method employed consisted of anodic treatment with 4 percent HNO_3 since this removes only the oxide and essentially no base metal. Analysis of the colored oxide showed it to contain approximately 21.5 percent chromium. Therefore, it was enriched in chromium considerably above the base chemistry of the steel. This is in agreement with results reported by Rhodin[4] and others.

Summary

Bright finished Type 430 stainless mill stock has been observed to show extensive surface etching upon atmospheric exposure in industrial areas. Such surface may be readily identified by five minute exposure to dilute sodium ferric chloride solution. Chemical analysis of the etch-susceptible surface layer shows it to be depleted in chromium as a result of short time annealing, while the accompanying oxide shows enrichment in chromium. Repetitive short time annealing and bright pickling treatments intensify the degree of chromium depletion while longer annealing times and higher temperatures tend to "anneal out" the surface gradient.

This suggests that during the early stages of annealing, chromium diffuses out of the subsurface layer and is oxidized at a much greater rate than the iron, leaving a chromium depleted layer immediately below the growing oxide film. As the oxide continues to grow it becomes more dense, acting as a barrier to further diffusion of chromium and/or oxygen ions. If heating is prolonged at this point, chromium from the core material will diffuse into the depleted layer to replenish that which was lost to the oxide. Hence an equilibrium is reached on a longer annealing cycle which removes all traces of the deleterious corrosion susceptible surface.

In addition to a longer annealing cycle, two other methods of removing the chromium depleted layer are apparent. One is a more complete pickling treatment after each high speed anneal to chemically dissolve the surface layer; another is mechanical abrasion of the surface.

Acknowledgments

The authors wish to express their gratitude to M. Cooper, R. Chance, and A. Ottolini of the General Motors Research Laboratories, Chemistry Department, who were most helpful in obtaining the chromium analyses and to J. L. Greene of the Metallurgical Engineering Department who was instrumental in devising the spot test for detecting chromium depletion.

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Any discussion of this article not published above will appear in the December, 1960 issue.

Corrosion Control in Petroleum Refineries Processing Western Canadian Crude Oils*

By C. L. EASTON

Abstract

Corrosion problems encountered in petroleum refineries processing Western Canadian crude oils, and the methods used to overcome them, are outlined. Hydrogen sulfide and other sulfur compounds, together with hydrochloric acid formed from chlorides in the water associated with the crude oils, are the chief factors in the corrosion of crude distillation units. Preventive measures include desalting, use of alloy materials, neutralization of the hydrochloric acid, and the use of film forming organic inhibitors.

Corrosion in catalytic cracking light ends equipment is attributed to nitrogen compounds and cyanides. Water washing to reduce cyanide concentration, the use of film-forming inhibitors, and the use of corrosion resistant materials are used with success to reduce the severity of the attack.

In catalytic reforming units, the problem of high temperature hydrogen sulfide corrosion is overcome by removing the sulfur in a feed preparation unit. Embrittlement of carbon steel by high temperature, high pressure hydrogen is a potential hazard in reforming units, but can be prevented by the use of refractory linings or low alloy steels containing chromium and molybdenum. Under certain conditions, strong acids are formed in these units creating further corrosion problems at temperatures below the dew point. 8.4.3

About the Author

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Introduction

CORROSION IS a major problem in most petroleum refineries. Many of these problems come about because of the nature of the crude oil being processed.

This paper outlines the main corrosion problems experienced in a number of Canadian refineries processing Western Canadian crudes, and the methods used in attempting to control the corrosion which occurs.

Cost of Corrosion

The cost of corrosion varies appreciably from refinery to refinery, depending on the size of refinery, the types of processing carried out, the types of crude processed, the presence of excess refinery capacity, and many other variables.

From time to time, different attempts have been made to estimate the cost of this corrosion in the Petroleum Industry. Due to the many variables involved, estimates have varied considerably, but a good representative estimate is still the API figure of $0.11 per barrel of crude. A breakdown of this figure is shown in Table 1, where it can be seen that maintenance costs are the greatest single item.

Any overall picture of corrosion costs should show the costs in the various phases of operation,

1. Producing
2. Refining
3. Transportation
4. Marketing

A breakdown of typical corrosion costs in these various phases is shown in Table 2.

It can be seen that refining costs represent about 65 percent of the total corrosion cost. While a proportion of this refining cost is inevitable, appreciable savings can be effected through the use of adequate control measures.

Table 2 also shows an estimate of corrosion costs in the Canadian Petroleum Industry in 1957.

Types of Crudes

Western Canadian crude oils are obtained from an appreciable number of fields, and vary from "sweet" to "sour," with the sour varieties predominating.

Normally, two or more blends of these crudes are processed at most refineries, and consequently over any 12 month period any one refinery may handle appreciable quantities of half a dozen or more crudes from different fields. In addition, segregated crudes, or blends of crudes, may be processed for special products such as lubricating oils, asphalts, etc. Table 3 indicates the number of different crudes processed at several Canadian refineries.

Because of the variety of crudes processed at any one refinery, it is sometimes difficult to determine accurately the corrosion resulting from any one crude. Over a period of years, however, it has been possible to detect certain trends, and these trends have been helpful in the design of new equipment.

Corrosive Contaminants

Corrosion by crude oil is generally attributed to the presence and stability of relatively small amounts of the following compounds.

1. Sulfur and its compounds
2. Inorganic salts
3. Mineral and organic acids
4. Nitrogen compounds
5. Vanadium compounds

Contaminants in Western Canadian Crudes

Sulfur and Sulfur Compounds. The sulfur content of these Western Canadian crudes is usually less than 1 percent. A few heavier crudes which are processed for special products such as asphalt, have sulfur contents in the range 2.0-3.5 percent.

Sulfur and hydrogen sulfide contents of some typical Western Canadian crudes are shown in Table 4. For comparison typical South American crudes processed in Eastern Canadian refineries are also shown. It can be seen that while the total sulfur of Western Canadian crudes tends to be lower, the hydrogen sulfide content tends to be higher.

Inorganic Salts. As received by the refineries, these crudes usually contain appreciable amounts of inorganic salts (see data in Table 4). By comparison, the South America crudes contain much less salt.

Nitrogen Compounds. Corrosion in certain processing equipment, particularly catalytic cracking light ends equipment, is often attributed to nitrogen complexes.

Although a certain amount of corrosion of this type has been experienced on light ends equipment, it is generally considered to be moderate where Western Canadian crudes are being processed. Greater problems have been experienced in refineries handling South American crudes.

Organic Acids. Organic acids such as naphthenic acid are not considered to be a source of corrosion where Western Canadian crudes are being processed.

Vanadium Compounds. Although some Western Canadian crudes contain small amounts of vanadium compounds, vanadium corrosion is not considered to be a problem. Where South America crudes have been processed, the vanadium compounds present have led to corrosion problems in some equipment.

General. The corrosive contaminants in Western Canadian crudes are sulfur,

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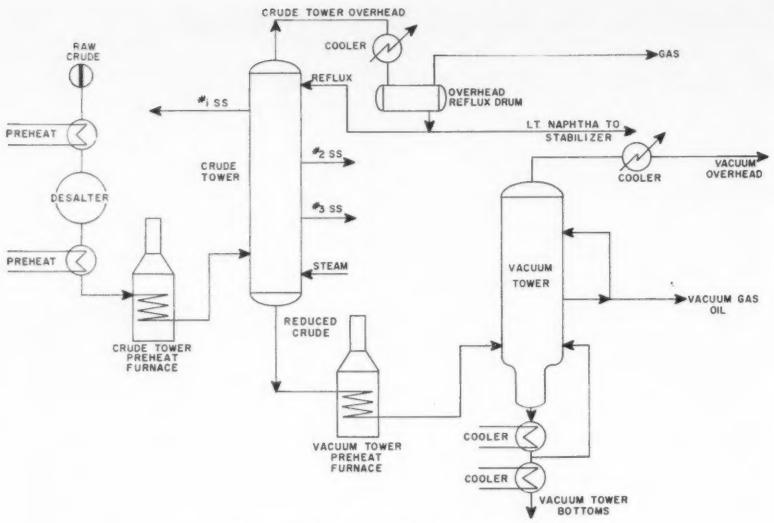

Figure 1—Simplified oil flow through crude distillation unit.

sulfur compounds, salts, and nitrogen compounds.

Hydrogen sulfide and salt are responsible for the appreciable low temperature corrosion experienced in overhead equipment. High temperature corrosion in furnaces and equipment operating at temperatures above about 500 F is attributed to sulfur and sulfur compounds.

In catalytic cracking light ends equipment, the severe localized corrosion is attributed to polysulfides and nitrogen complexes.

Corrosion in Crude Distillation Units

Oil flow in a typical crude distillation unit is shown in Figure 1.

Desalting of Crude Oil

Efficient desalting of the crude oil has been found to be extremely desirable if Western Canadian crudes are being processed, as appreciable amounts of salts are associated with most of these crudes. If the bulk of the salt is not removed, considerable trouble results due to plugging of equipment, and corrosion by hydrochloric acid.

The salt content of these crudes can range from 2 to 200 lbs./1000 bbl. of crude, with the bulk of the crudes averaging well over 25 lbs./1000 bbl. Typical values are included in Table 4. With normal commercial desalting equipment, the salt content can be lowered to about 5 lbs./1000 bbl.

At this latter salt level, the salts remaining in the 'desalted' crude are still capable of forming appreciable amounts of free hydrochloric acid in the distillation towers. Normal practice is to neutralize this acidity by injecting ammonia into the upper part of the distillation tower. If no crude desalting is carried out, this ammonia injection into the tower can result in complete plugging of trays and reflux piping due to the formation of ammonium salts. Where crude desalting has been carried out, ammonium salt deposition has not been a problem.

Serious corrosion can occur in the actual desalting equipment. In one case, the lower part of a carbon steel desalting sphere corroded by 1/16" within six months after the original installation (corrosion rate 1/8 ipy). Protection of this sphere was accomplished by installing a protective layer of concrete over the corroded area. Little or no maintenance of this concrete lining has been necessary during the past seven years. Similar corrosion of a less severe nature has been experienced on spheres on other units, and concrete linings have been successful where used.

Corrosion of carbon steel is also experienced on the sludge removal systems on these crude desalters. Periodic renewal of piping is necessary. Corrosion of critical components has been prevented through the use of austenitic stainless steels.

Atmospheric Tower Preheat Furnace

Prior to entering the crude distillation tower, the crude oil is given a final preheat in a furnace. Despite variations in the crudes, the same basic corrosion pattern develops in the majority of these furnaces.

At the cooler, inlet zone of each furnace, corrosion losses are extremely light and carbon steel tubes give excellent service. Corrosion has not been a problem in this zone.

In the hotter, outlet zone of the furnace, the crude oil is raised to temperatures in excess of 600 F. Under these conditions, carbon steel tubes suffer severe pitting and corrode at about 1/16 inch per year. Low alloy steels, such as 4-6 percent Cr, 1/2 percent Mo, have shown reduced corrosion rates, and with this material metal losses are now 1/64 inch per year or less.

Unconfirmed reports from other sources however, indicate that certain Western Canadian crudes can cause corrosion of 4-6 percent Cr, 1/2 percent Mo alloy steel at rates in excess of 1/16 inch per year, if the crude oil temperature is raised to about 700 F.

Transfer piping between the furnaces and the towers also suffer from this high temperature corrosion. On some units, the rate of corrosion on carbon steel piping has been as high as 1/16 inch per year, and severe pitting has occurred. Piping of the composition 4-6 percent Cr, 1/2 percent Mo has been installed on these units.

This high temperature corrosion in the furnaces and transfer lines is attributed to the sulfur and sulfur compounds in the hot crude.

Crude Distillation Towers

Lower Section. After the final preheat, the hot crude enters the tower near the bottom. Generally, some corrosion occurs in this zone of the tower, particularly if the hot oil impinges onto the carbon steel. On some units, unlined carbon steel

TABLE 1—Cost of Corrosion—Breakdown of API Estimate

Breakdown	API Survey
Built-in costs	$0.021 /bbl.
Maintenance costs	0.071
Lost Production Costs	0.018
Tools and Inventory Costs	0.0025
Total Corrosion Cost	$0.1125/bbl.

TABLE 2—Cost of Corrosion—Cost of Various Phases of Operation

Phase of Operation	Estimated Corrosion Cost, $/bbl.	Approximate Cost of Corrosion in the Canadian Petroleum Industry in 1957 (Based on Estimated Corrosion Cost)	
		All Canada	Imperial Oil Limited
Producing	0.02	3,500,000*	800,000*
Refining	0.07	(16,000,000** (18,500,000***	6,800,000**
Transportation	0.01	2,500,000	1,000,000
Marketing	0.01	2,500,000	1,000,000

* Based on crude oil produced in Canada.
** Based on total product manufactured in Canada.
*** Based on total product sold, including both domestic and imported supplies.

TABLE 3—Number of Crude Oils and Blends Processed at Various Canadian Refineries

Refinery	No. of Blends*	Total Number of Crudes**
A	..	6
B	..	2
C	..	7
D	2	8
E	3	7

* "Blend" is made up of a mixture of crudes from two or more fields.
** "Crude" refers to crude oil from a single field.

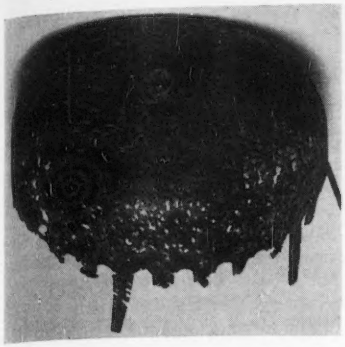

Figure 2—Appearance of 11-13 percent chromium alloy steel bubble-cap from top tray of crude distillation tower after two months' service. Original thickness 0.065 inch.

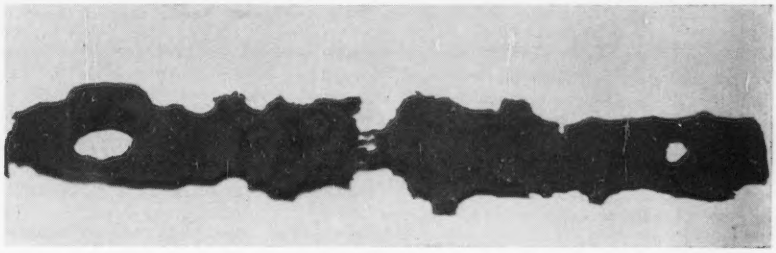

Figure 3—Appearance of carbon steel bubble-cap hold-down strap after three weeks' service in upper part of naphtha rerun tower.

has been used successfully in this zone. On other units, however, serious corrosion has been experienced, and the carbon steel has had to be protected. Both concrete and various austenitic stainless steel linings have provided good protection, although concrete linings require a certain amount of periodic maintenance.

Top Section. Under normal operating conditions, some condensation occurs in the upper part of these crude towers. Consequently acidic corrosion due to the combination of hydrochloric acid and hydrogen sulfide can occur.

Sufficient hydrochloric acid is evolved by the hydrolysis of the salts remaining in the 'desalted' crude to produce pH values of 1 to 3 in the overhead reflex drum water draw-off.

Thus, in the upper part of the tower, unprotected carbon steel and stainless steels are rapidly attacked. Figure 2 shows the condition of a 11-13 percent Cr stainless steel bubble cap after three months' service in the top tray of one of these crude towers. The original thickness of this bubble cap was 0.065 inch. An example of a carbon steel bubble cap holddown strap after only 3 weeks in a similar service is shown in Figure 3.

Effective protection in this top zone of these towers is obtained through the use of Monel tray components, and Monel linings over the carbon steel shells. Concrete linings are not normally used in this area, because of the amount of maintenance required.

Ammonia is injected into the upper section of each crude tower to neutralize the hydrochloric acid. This assists in protecting the overhead equipment. The author's experience has been that ammonia injection directly into the overhead stream is inefficient and tends to lead to localized protection of the overhead equipment. Injection of the ammonia directly into the tower appears to provide better mixing. Deposition of ammonium salts in the tower is not a problem with desalted crudes, but with undesalted crudes, complete plugging of trays and draw-off piping can rapidly occur.

The rate of injection of ammonia into the tower is controlled by maintaining a close control of the pH of the condensate water draw-off. The pH of this draw-off water is maintained at the level 6.5-7.0.

Crude Distillation Tower Overhead Equipment

The corrosion experienced in the overhead equipment is of an acidic type, similar to that found in the upper part of the crude towers. Corrosion is most severe at the point of initial condensation, which is usually in the overhead condensers.

Both carbon steel and inhibited Admiralty brass are severely attacked if Western Canadian crudes are being processed. Carbon steel overhead lines show corrosion rates of up to $\frac{7}{64}$ inch per year, while carbon steel condenser shells and distillate drums show corrosion rates as high as $\frac{15}{64}$ inch per year. Inhibited Admiralty brass condenser tubes also show high corrosion rates, in excess of $\frac{1}{16}$ inch per year.

Low temperature hydrogen blistering of carbon steel condenser shells and distillate drums has been experienced on several units, where adequate precautionary measures have not been taken.

Protection Procedures in Overhead Equipment. Because of the severe corrosion which can occur in this overhead equipment, adequate preventative measures must be taken. These steps are as follows:

1. Use of Metals. Where hydrogen sulfide concentrations have been low, such as in the case of the South American crudes shown in Table 4, 70/30 cupronickel condenser tubes have given satisfactory service. However, with the higher hydrogen sulfide concentrations associated with Western Canadian crudes, both 70/30 cupro-nickel and Monel have shown corrosion rates of about $\frac{1}{64}$ inch per year even when ammonia was being used to neutralize the acids present.

Current practice is not to use special metals in the overhead equipment provided both ammonia and an organic corrosion inhibitor are being injected to control the corrosion. Normally, steel with inhibited Admiralty brass condenser tubes would be specified.

2. Use of Non-Metallic Materials. Nonmetallic linings, such as concrete, have been used successfully, against both acidic corrosion, within certain limits of acidity, and also for low temperature hydrogen attack.

However, linings of this type can only be applied to certain equipment, such as reflux drums, etc. Other equipment, such

TABLE 4—Corrosive Contaminants in Typical Western Canadian and South American Crude Oils

Name of Crude	Total Sulphur Weight Percent	Evolved H_2S, Lb./1000 Bbl.	Salt Content, Lb./1000 Bbl.	HCl by Evolution, Lb./1000 Bbl.	Nitrogen Content, Weight Percent	Nitrogen Content of Heavy Gas Oil, Weight Percent
Western Canadian Crudes:						
Leduc—Woodbend	0.28	23–110	20–160	10	0.11	0.11
Redwater	0.69	54–160	35–100	22	0.12	0.16
Sturgeon Lake	0.42	45	35–60	4	0.09	0.16
Pembina	0.18	3	2	Nil	0.08	0.06
S.E. Saskatchewan	0.80	32	145	7.4	....	0.08
Cremona	0.49	82	38	1	0.02	0.05
Conrad	2.1	64	15	Trace	....	....
Manitoba	1.51	83	9	4	....	0.09
South American Crudes:						
Tia Juana Med.	1.65	0.9	6	....	....	....
Guanipa	1.0	..	5	....	....	....

TABLE 5—Reduction in Corrosion Losses on Overhead Equipment Through the Use of an Organic Film-forming Inhibitor

Protection Provided		Condition of Crude Tower Overhead Equipment at Yearly Inspections		
Ammonia Injection	Inhibitor Injection	Condenser Tubes (Inhibited Admiralty Brass)	Condenser Shells (Steel)	Reflux Drum (Steel)
Yes	No	Tubes holed Bundle retubed.	$\frac{15}{64}$" loss	Hydrogen blistering
Yes	For six months only	Tubes thinned Bundle retubed.	$\frac{7}{64}$" loss	Old drum blistered. New drum installed.
Yes	Intermittent	Good Condition	$\frac{2}{64}$" loss	$\frac{3}{64}$" loss
Yes	Continuous	$\frac{1}{64}$" loss on O.D. tubes. Good Condition	$\frac{1}{64}$" loss (average)	No loss

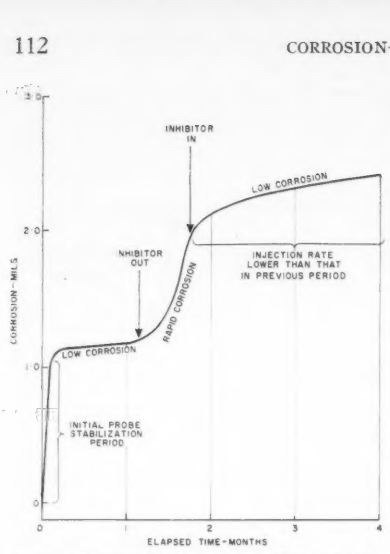

Figure 4—Response of electrical resistance probe to variation in inhibitor injection rate.

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3. Use of Chemicals. Shortly after the introduction of Western Canadian crudes, it became evident that ammonia injection by itself was not effective in preventing serious attack of both carbon steel and inhibited Admiralty brass in overhead equipment.

The effect of injecting organic film forming inhibitors into the overhead line was studied under plant conditions. Ammonia injection was maintained at the same level as before, since optimum inhibitor protection occurred under neutral pH conditions. Table 5 shows the marked reduction in actual metal losses in the overhead equipment on one unit after inhibitor injection into the overhead line was introduced. Similar reduced corrosion losses have been recorded on other units following the introduction of organic inhibitor injection.

As a result, present practice is to inject both ammonia and an organic inhibitor into all crude units to protect overhead equipment. The ammonia is injected into the tower, while the organic inhibitor is injected into the overhead line. Inhibitor injection is carried out on a continuous basis, normally at about ¼ USG/1000 bbl. overhead. Following shutdowns, this dosage rate is doubled for the first week or so, until the protective film on the metal is fully developed. The ammonia injection rate is maintained at a level which provides a pH of about 6.5 to 7.0 in the water draw-off from the overhead reflux drum.

Cost of Chemical Protection. Although the initial outlay is relatively small, protection by means of ammonia and inhibitor injection is a recurring cost and is not cheap. Typical yearly costs of these chemicals on three different crude distillation units are shown in Table 6.

The cost of protection per barrel of crude processed varies appreciably from unit to unit. It is dependent on the crude being processed, the cost of chemicals at each refinery location, and many other operating variables. An example of this is the 25,000 B/D unit shown in Table 6.

TABLE 6—Typical Yearly Cost of Chemicals for Corrosion Protection in Typical Crude Unit Overhead Equipment

Size of Crude Unit	Ammonia		Organic Inhibitor	
	Injection Rate, lb/1000 bbl.	Cost, $/Year	Injection Rate, USG/1000 bbl.	Cost, $/Year
15,000	2.0	1,800	0.2	1,800
25,000	4.0	4,300	0.35	4,500
50,000	2.0	3,500	0.25	5,000

On this unit, the crudes being processed require much more ammonia to neutralize the evolved acidity than do those being processed on the other two units. In addition, the optimum inhibitor injection rate on this unit is also higher.

Control of Inhibitor Injection Rate. Excessive inhibitor injection rates can cause foaming, loss of product, and other operating problems. Also, as was shown in Table 6, the yearly cost of inhibitor injection is not particularly low.

Consequently, it is desirable to maintain the inhibitor injection rate at the lowest level which provides adequate protection.

A measure of the protection being provided by the combined action of the ammonia and organic inhibitor is obtained by measuring the iron and copper content of the water draw-off from the overhead drum. Experience has shown that these iron and copper content figures cannot be used to predict actual corrosion rates, since the corrosion is very often localized or takes the form of pitting.

However, if used properly, these iron and copper determinations are extremely helpful in determining and maintaining optimum injection rates.

Retractable coupons have been used also to determine if inhibitor protection is being obtained. Such coupons are helpful, but suffer from an inherent disadvantage that a relatively long exposure period is normally required.

Recent developments with electrical resistivity probe methods provide a much more rapid evaluation of the protection being obtained. The effect of variation in injection rate, or of changing the inhibitor can be obtained quickly. The rapid response of an electrical resistance probe to variation in inhibitor injection rate is shown in Figure 4. It can be seen that the probe responds within a few days to any change in the injection rate.

Where corrosion rates have been relatively high, it has been found that wire type probes tend to provide a more satisfactory service life than do strip or tube type probes. Premature probe failures have been reported, due to erosion by solids entrained in the hydrocarbon stream, or to insulation breakdown.

Coupons and probes provide corrosion data for spot locations only. The measurements obtained are best suited for showing trends in corrosion rates, particularly in conjunction with inhibitor injection programs. General corrosion rates can be safely predicted if the history of the equipment indicates that the equipment corrodes fairly evenly. However, if localized corrosion tends to occur, the use of coupon and probe measurements to predict actual corrosion rates should be avoided, if possible.

Vacuum Towers and Associated Equipment. The reduced crude from the bottom of the crude distillation tower is heated to a temperature of 750 F or greater, in a furnace, prior to entering the vacuum distillation towers.

Corrosion in these furnaces has not been a problem. Carbon steel tubes provide satisfactory service.

This hot reduced crude however, can cause serious corrosion in the lower part of vacuum towers. Corrosion rates of up to ⅛" per year have been experienced on unprotected carbon steel shells. Deep pitting also occurs.

On most units therefore, some type of protection has been found to be necessary. Both austenitic stainless steel strip linings and concrete linings have been used successfully to protect the carbon steel shells.

This corrosion is attributed to the breakdown of non-corrosive sulfur compounds in the reduced crudes. Hydrogen sulfide is one of the corrosive compounds which are formed.

On some units, additional free hydrochloric acid is also generated. Acidic water is found in the overhead equipment, and pH values in the range 2.0 to 3.0 have been obtained. Where low pH values occur, ammonia injection is being used to control the pH at 6.5 to 7.0, and on some units, organic inhibitors are also being injected. As a result of these combined measures, no serious corrosion of this overhead equipment has been reported.

Corrosion in Catalytic Cracking Units

On catalytic cracking units, the usual problems of high temperature oxidation of carbon steel, and catalyst erosion, are experienced in the cracking section of each unit.

Corrosion in light ends distillation equipment varies from unit to unit, and appears to be affected by the actual feed stock being processed. Where the catalytic cracking unit feed stock originates from Western Canadian crudes, the corrosive constituents follow the liquid stream, particularly the C_4 and lighter streams. With these feed stocks, corrosion is generally light, and little or no hydrogen blistering has occurred. By contrast, where South American crudes are being handled, severe hydrogen blistering has occurred in some catalytic light ends equipment.

Oil flow through typical light ends equipment is shown in Figure 5.

During the cracking operation, appreciable amounts of ammonia are formed from nitrogen compounds in the various feed stocks. In the main fractionator overhead stream, pH values normally reach a value of between 8.5 and 9.0. Despite such high pH values, corrosion

of the inhibited Admiralty brass tubing in the overhead condensers has been extremely light on most units, and little or no corrosion of carbon steel equipment occurs.

However, downstream of the main fractionator overhead equipment, polysulfides and nitrogen compounds have caused serious corrosion of isolated pieces of equipment. The presence of cyanides has been detected in some units which experienced serious corrosion.

Corrosion on gas compressor aftercoolers has been particularly severe. In one unit for example, inhibited Admiralty brass condenser tubes with a 0.065 inch wall (16 BWG) corroded and was penetrated within 30 days. Further details of this particular condenser problem are given later.

Where serious corrosion has been experienced on catalytic light ends equipment, the following methods of preventing further attack are normally used:

1. Organic inhibitors are used together with a water wash to reduce pH and cyanide concentration.
2. Corrosion resistant materials are used.

The water wash is generally added at the low pressure distillate pump. The injection of the corrosion inhibitor is usually at one or more of the points shown in Figure 5.

In many instances, injection of inhibitor together with water washing, has been a relatively simple remedy to the corrosion problem. In other instances, however, the solution to the problem has not been straightforward. One such problem is outlined as follows:

Case History of Gas Compressor Aftercooler Bundle

Following the initial start-up of the unit, the original 16 BWG inhibited Admiralty brass tubes corroded through within 30 days. The first attempt to reduce this corrosion was by water washing the hydrocarbon stream with untreated river water. This resulted in the pH dropping from 8.8 to 8.0, while the corrosion rate appeared to be slightly reduced, based on iron and copper analyses of the condensate water draw-off. A much greater reduction in iron and copper content was obtained by lessening the water wash rate and introducing an organic inhibitor. Substitution of treated river water for the untreated river water reduced iron and copper content still further.

The effect of these various treatments on the condensate water draw-off is shown in Table 7.

At this stage the problem seemed to be under control. However, subsequent experience showed that although the general corrosion rate was negligible, localized breakdown of the organic inhibitor film occurred. Unexpected tube failures due to isolated pitting were experienced. Impingement of the hydrocarbon stream on the tubes appeared to have occurred at the points of failure. An example of the pattern found is shown in Figure 6.

In the meantime, alternative tube materials were being tested in the bundle. Aluminum brass, 70/30 cupronickel, and Monel, all showed general corrosion or pitting. Type 304 stainless steel was ruled out on an economic basis although it appeared to be fully corrosion resistant.

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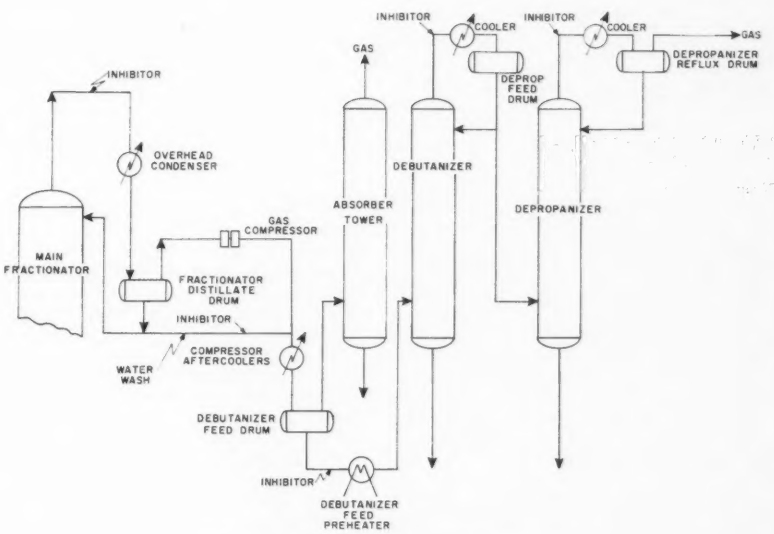
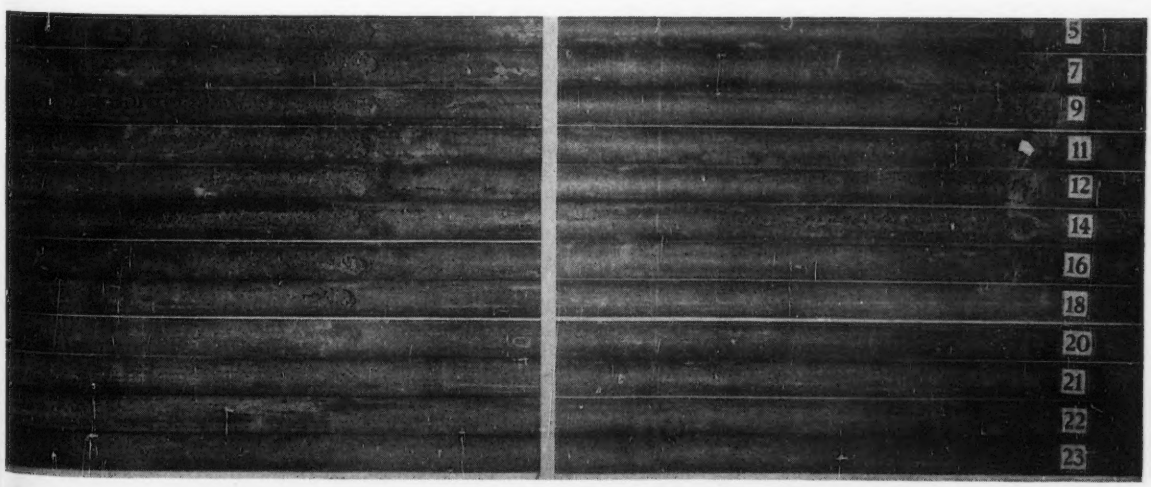


Figure 5—Typical flow through light ends equipment.



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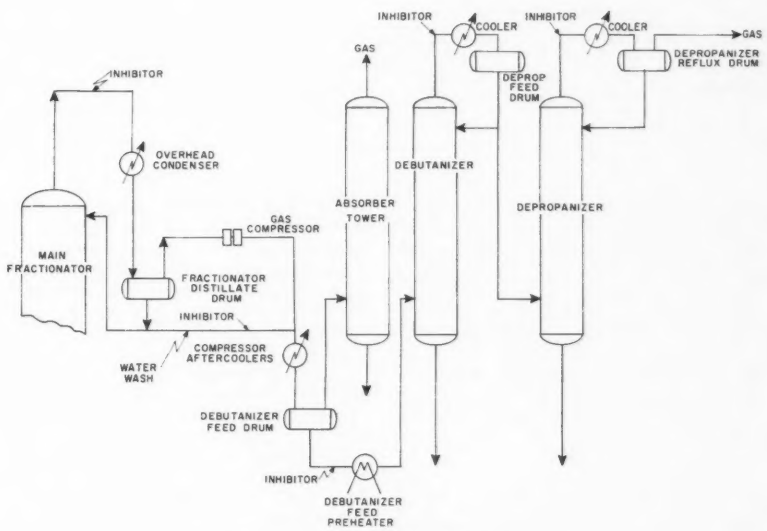

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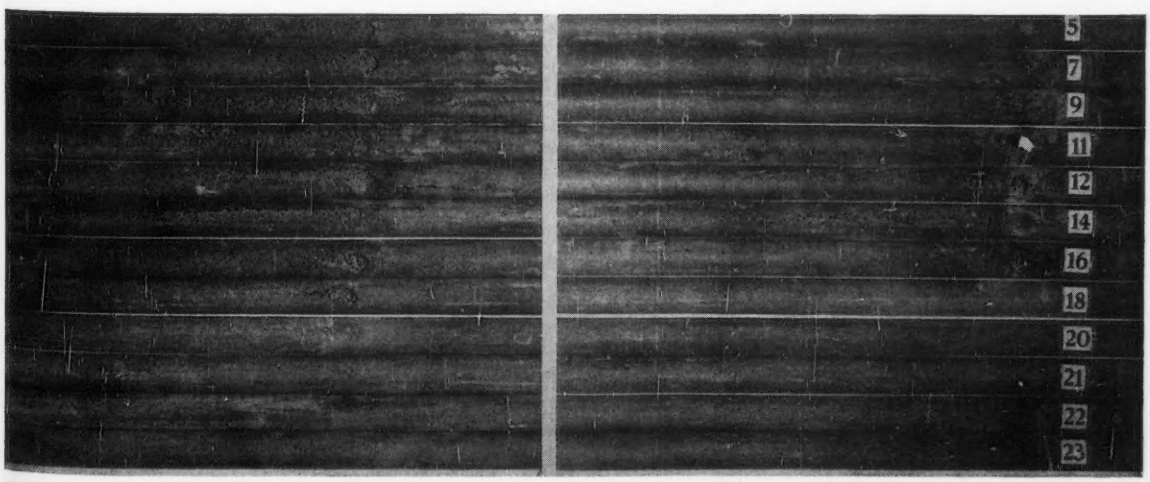

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Figure 7—Blistering of carbon steel by high temperature, high pressure hydrogen.

TABLE 7—Corrosion in Gas Compressor Aftercooler (Effect of Preventive Measures on pH, Iron Content, and Copper Content of Water Draw-off Stream)

Preventive Measures		Draw-off Water Analyses		
Water Wash, US Gallons Per Minute	Inhibitor Injection, US Gallons Per Day	pH	Iron Lb./Day	Copper Lb./Day
Nil	Nil	8.8	8.8	1.5
25 (Untreated water)	Nil	8.0	6.0	0.72
5 (Untreated water)	5.0	8.4	1.5	0.24
5 (Treated water)	5.0	8.4	0.6	0.12

suitable for condenser tube service because of its susceptibility to fouling and pitting by the river water used for cooling. However, this fouling and pitting tendency appeared to be less undesirable than the premature failure of inhibited Admiralty brass due to pitting and erosion. Consequently steel tubes were installed, and these have performed satisfactorily to date. The steel has been fully resistant to the hydrocarbon stream, while fouling and pitting by the cooling water has not been excessive.

Although periodic renewals of the steel tubes will probably be necessary, it appears that the combination of water washing, inhibitor injection, and the use of carbon steel tubes, is a practical remedy to this problem.

Corrosion in Catalytic Reforming Units

The main potential corrosion problems in catalytic reforming units are:

1. Embrittlement due to the use of high pressure, high temperature hydrogen.
2. Corrosion due to high temperature hydrogen sulfide in hydrogen rich atmospheres.

High Pressure, High Temperature, Hydrogen

The consequence of exposure of carbon steel to high pressure, high temperature, hydrogen is well known. Hydrogen attack is particularly hazardous since normally there is no outward appearance that embrittlement is occurring. In one instance, a carbon steel component with a normal outward appearance had become embrittled to a point where the strength had decreased from 55,000 psi to zero.

Although this hydrogen attack is characterized by a lack of outward evidence that embrittlement of the metal is occurring, blistering was found on one occasion, in a non-critical carbon steel component exposed to high temperature, high pressure hydrogen. The reason for this blistering, which is shown in Figure 7, is not known.

In the smaller equipment items, such as heat exchangers, furnace tubing, piping, etc., hydrogen attack has been prevented through the use of carbon-molybdenum or chromium-molybdenum alloy steels. Depending on the operating conditions, C-½ Mo, 1¼ Cr ½ Mo, 2¼ Cr 1 Mo, or 5 Cr ½ Mo, have been used successfully.

In the larger equipment items, these low alloy steels and non-metallic refractory lined carbon steel have been used successfully. The non-metallic linings lower the operating temperature of the carbon steel, provided that they are carefully applied. Poor linings can be permeated by hot hydrogen, resulting in localized overheating of the metal.

Pressure build-up in reaction vessels due to scale accumulation on top of the reactor beds, can also result in penetration of the refractory lining by hot hydrogen. This penetration can be prevented by installing metallic shrouds on top of the refractory lining.

High Temperature, Hydrogen Sulfide Corrosion

Based on data available to date, this type of corrosion seems to have been largely avoided by removing the sulfur in a hydrofining feed preparation stage. In the hydrofiner, sulfur removal is carried out at the relatively low temperature of 500 - 700 F where hydrogen sulfide corrosion is light.

With efficient sulfur removal in the hydrofining stage, high temperature hydrogen sulfide corrosion in the reforming stage has been exceedingly low. However, where sulfur removal has been incomplete, serious corrosion can soon develop. On one unit, the 2¼ Cr 1 Mo alloy steel tubes in three reformer reheat furnaces showed a 3/64" to 4/64" wall loss in a two month period (18/64" per year). During this period, the hydrogen sulfide concentration in the total reformer reactor feed was 0.0272 mol percent. Normal corrosion rates on these furnace tubes, with normal sulfur levels is approximately 1/64" per year.

Where the catalytic reformer feed originates from a relatively sweet crude, sulfur removal in a hydrofining stage is not necessary. In one unit, the sulfur in the feed averages about 125 ppm (nominal 200 ppm), and corrosion has not been excessive, although it is somewhat higher than on units with hydrofining equipment. Maximum corrosion has occurred on the low chromium alloy steel furnace transfer piping, where the corrosion rate varies from 0 to 2/64" per year. On this unit, scale formation presents more of a problem than corrosion. It is believed that scale formation would cease to be a problem if the sulfur content were reduced below 0.0075 mol percent.

With catalytic reformer feeds from other Western Canadian crudes, the sulfur content varies considerably but may be up to 1000 ppm. At these higher sulfur levels, hydrofining is essential, if corrosion is to be kept low.

Low Temperature Hydrochloric Acid Corrosion

It is believed that where chlorinated solvents are used during the transportation of the crude, chloride contamination of the catalytic reformer feed can occur. These chlorides are converted to hydrogen chloride in the hydrofining stage, and hydrochloric acid corrosion can occur in condensing equipment.

Corrosion from this source has not been experienced in refineries handling Western Canadian crudes. However, some hydrochloric acid corrosion of condensing equipment has occurred where chlorine has been stripped from the platinum catalyst.

Conclusion

Most Western Canadian crudes can cause serious corrosion in refinery process equipment and adequate preventive measures are essential if corrosion is to be held at a reasonable level.

Corrosion control is not easy at any time, even in large integrated refineries handling only one or two different crudes. With widely scattered refineries, each processing a changing variety of crudes, the problem of good corrosion control is much more difficult.

Despite this basic difficulty, control of corrosion by Western Canadian crudes can be achieved through the use of preventive measures such as those outlined.

Hydrogen Corrosion in Organic Reactor Coolants*

By V. H. TROUTNER

Part 1—Hydriding of Zirconium

Abstract

Zirconium and Zircaloy-2 were exposed to organic reactor coolants at temperatures up to 400 C under various conditions of constant hydrogen partial pressure and low water concentration. The hydriding of zirconium was found to be independent of the presence of the organic coolant and dependent on the temperature, hydrogen partial pressure, and the presence of an oxide film on the metal. 6.3.20

About the Author

V. H. TROUTNER is engaged in the study of aluminum corrosion at the Hanford Atomic Products Operation, Richland, Washington. He received a BS in chemistry from the University of California and an MS from the University of Idaho. He is a member of ACS.

Introduction

ORGANIC FLUIDS are contemplated for use as nuclear reactor coolants because they offer several advantages over an aqueous coolant. They can operate at high temperatures and relatively low pressures. In the absence of water, or at very low water concentrations, they are not corrosive to materials of reactor construction.[1] However, in the presence of hydrogen, which is formed from pyrolytic and radiolytic decomposition of the organic fluid, both uranium and zirconium alloys are damaged. Part one of this study describes the hydrogen corrosion of zirconium alloys in organic coolants in the presence of hydrogen and low water concentrations.

In a preliminary experiment, Bowen[2] exposed a sample of zirconium in MIPB at 375 C for 28 days in a sealed vessel. The pressure increased during the exposure from 65 psia to 225 psia primarily as a result of hydrogen accumulation. The sample was severely hydrided and cracked as shown in Figure 1. In another experiment[2] samples of zirconium were exposed in MIPB at 300 C and 375 C in a refluxing apparatus which was swept out with an inert gas to prevent hydrogen accumulation. After a four-month exposure there was no damage to the samples.

Experimental

The organic compounds used in these experiments were biphenyl and monoisopropylbiphenyl (MIPB). The biphenyl was used as representative of the unsubstituted aromatic organic coolants, and was commercial grade material. The MIPB was used as representative of the aliphatic substituted organic coolants, and was the commercial isomeric mixture of 62 percent meta and 38 percent para. Because MIPB was easier to handle than biphenyl, which is solid at room temperature, most of the experiments were conducted using MIPB.

Tests were run in MIPB in the following three conditions:

1. Freshly received with 60 ppm water analysis
2. Stored in moist atmosphere to give 150 ppm water analysis
3. Material 2 dried with magnesium turnings at 295 C to give 100 ppm water analysis

*Submitted for publication March 2, 1959.

TABLE 1—Hydriding of Zirconium in MIPB Containing 60 ppm Water

Temperature, Degrees C	Hydrogen Partial Pressure, psi		Hydrogen Content of Zirconium After 6 Day Exposure, ppm	
400	1.5	...	700–8700	...
400	...	0.3	...	200–370
350	3.5	...	140–975	...
350	...	0.7	...	30–90
300	5	...	5–38	...
300	...	1	...	2–3
250	5	...	3–5	...
250	...	1	...	1
210	5	...	10–11	...
150	5	...	10	...

TABLE 2—Hydriding of Zirconium in MIPB Containing 150 ppm Water

Temperature, Degrees C	Hydrogen Partial Pressure, psi	Hydrogen Content of Zirconium After 6 Day Exposure, ppm
400	5	80–130
350	5	40–100
300	5	19–43

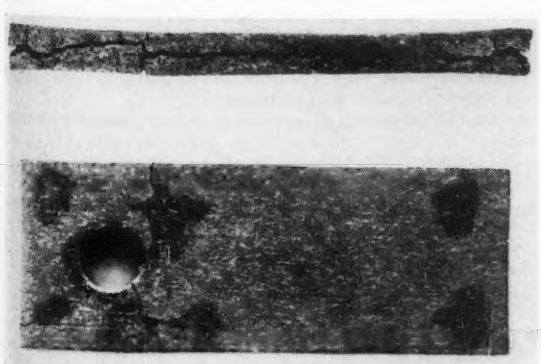

Figure 1—Zirconium hydrided in MIPB for 28 days at 375 C, 210 psig maximum pressure

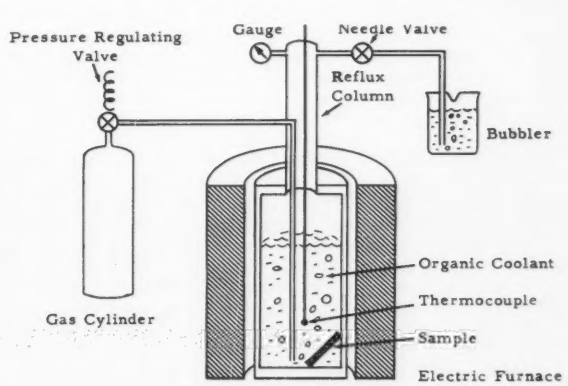

Figure 2—Hydriding apparatus

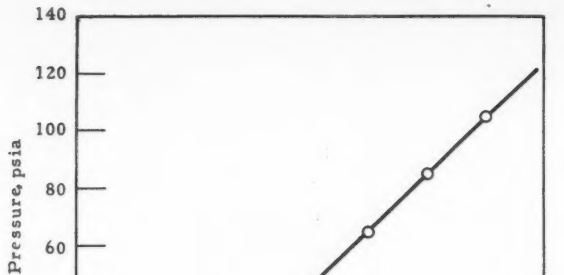

Figure 3—Vapor pressure of MIPB

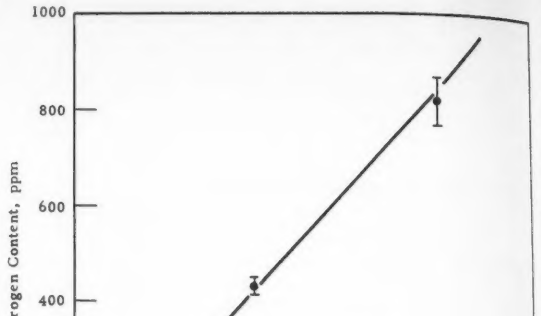

Figure 4—Hydriding of zirconium in MIPB

TABLE 3—Hydriding of Zirconium in MIPB Containing 100 ppm Water

Temperature, Degrees C	Hydrogen Partial Pressure, psi	Hydrogen Content of Zirconium After 6 Day Exposure, ppm
400	5	460–630

TABLE 4—Effect of MIPB* on Hydriding of Zirconium

Temperature, Degrees C	MIPB	Hydrogen Partial Pressure, psi	Hydrogen Content of Zirconium After 6 Day Exposure, ppm
350	Yes	3.5	140–975
350	No	3.5	275–443

* MIPB containing 60 ppm water.

TABLE 5—Time Dependence of Zirconium Hydriding in MIPB*

Temperature, Degrees C	Exposure Time, Hours	Hydrogen Partial Pressure, psi	Hydrogen Content of Zirconium After Exposure, ppm
350	0	3.5	3–12
350	84	3.5	415–449
350	338	3.5	770–870

* MIPB containing 60 ppm water.

Zirconium and Zircaloy-2 coupons (½ x 1 x 1/16 inch) were used in the as-received condition. They were degreased in a trichloroethylene vapor degreaser prior to test.

Test exposures were conducted in the apparatus shown in Figure 2. A mixture of hydrogen and helium was supplied from the gas cylinder, at constant pressure, into the bottom of the test vessel where it bubbled up through the organic fluid and was released from the top of the refluxing column by a small valve. The gas then passed through a bubbler and was vented. The test vessel was heated by an electric furnace equipped with suitable temperature controls. The reflux column extended out of the furnace and prevented the loss of organic vapors. The temperature of the organic fluid in the test vessel was measured with a thermocouple. A gas flow rate of about 10 cc per minute was maintained as indicated by the bubbler.

The partial pressure of hydrogen in the test vessel was determined by the gas mixture and the total pressure. For example, at 350 C a mixture containing 5 percent hydrogen and 95 percent helium (by volume) at a total pressure of 145 psia, gave a hydrogen partial pressure of 5 psi, since the vapor pressure of MIPB at 350 C is 45 psia. For purposes of determining the hydrogen partial pressure, the MIPB vapor pressure curve determined by Bowen[2] was used. This curve is shown in Figure 3. The experimental uncertainty in measuring the hydrogen partial pressure was estimated as ± 10 percent.

A few static tests which were conducted were run in a similar apparatus which was not equipped with a reflux column or provisions for gas flow. The extent of hydriding of the zirconium during exposure was determined by vacuum extraction analysis.

Results and Discussion

The results obtained in the hydrogen pressure apparatus are given in Tables 1-5. All exposures were for six days. The hydrogen content of the zirconium samples prior to exposure was 3 to 12 ppm. Because the hydrogen analysis of duplicate samples after exposure covered a wide range of compositions, a range of hydrogen concentrations is herein reported. Consequently, only a qualitative treatment of the data could be attempted.

There was no difference observed in the behavior of zirconium and Zircaloy-2, so no distinction is made between these materials throughout this report.

The data shown in Table 1 were obtained using freshly received MIPB which had a water content of about 60 ppm. The hydrogen pick-up during exposure increased with increasing temperature. Below 300 C there was no significant hydrogen pick-up. At a given temperature the hydrogen pick-up increased with increasing hydrogen partial pressure.

The data given in Table 2 were obtained using MIPB which had been stored where it was exposed to conditions of high humidity. Analysis showed that the water content of the MIPB had increased to 150 ppm. The hydrogen pick-up was considerably less than that observed under similar conditions in the MIPB containing 60 ppm water. Some of this "wet" MIPB was partially dried by refluxing at 295 C with magnesium turnings. Analysis showed a water content of about 100 ppm. The results of the test run in this organic are given in Table 3. The hydrogen pickup at 400 C and 100 ppm water was greater than that at 150 ppm water, and less than that at 60 ppm water.

It appears that the rate of hydriding of zirconium decreases with increasing water content in the organic. This is reasonable since the water in the organic should have a marked effect on the oxide film on zirconium, and since it is known that the rate of zirconium hydriding is very sensitive of the nature of its oxide film.[3, 4]

The results of similar tests run with and without MIPB are given in Table 4. Although the hydrogen analyses showed a wide range of concentration, it appears that the presence of the MIPB had no effect on the rate of hydriding.

All of the previously discussed results were obtained from six day exposures. In order to determine the dependence on time of the hydriding process, a test was run at 350 C and 3.5 psi hydrogen in MIPB containing 60 ppm water. Duplicate zirconium samples were removed after 84 and 338 hours exposure. The results are given in Table 5. When these data were plotted as a function of the square root of time, Figure 4, a straight line was obtained, indicating a diffusion controlled process. However, considering the small number of experimental observations and the wide range of hydrogen concentrations obtained for a given set of conditions in other experiments, the conclusion that the process is diffusion controlled is highly tentative.

A consideration of some importance is the maximum extent of zirconium hydriding under a given set of conditions. There were no long term tests run to determine the extent to which zirconium can hydride. It is thermodynamically reasonable to assume that if the partial pressure of hydrogen exceeds the dissociation pressure of zirconium hydride, then the zirconium can be completely converted to the hydride.

The dissociation pressure for ZrH_x at a given temperature is a function of the value of its hydrogen content, x. For example, at 400 C the dissociation pressure of $ZrH_{1.95}$ is about 0.06 psi (extrapolated from data of Gilbert[5, 6]). Consequently, any hydrogen pressure greater than 0.06 psi is sufficient to hydride zirconium to a composition of $ZrH_{1.95}$, which corresponds to about 21,000 ppm hydrogen content. A hydrogen pressure in excess of 0.0023 psi is sufficient to hydride zirconium to a composition of $ZrH_{1.90}$, or 20,600 ppm hydrogen content. It is apparent that very low partial pressures of hydrogen can cause almost complete hydriding of zirconium. From a practical standpoint the rate of hydriding is far more important than the maximum theoretical extent of hydriding. Very low rates can give a long useful life for zirconium. The rate of hydriding is a function of temperature, hydrogen pressure, and the nature of the surface oxide film.

Conclusions

Zirconium reacts with hydrogen to form zirconium hydride. The presence of the organic coolant has no effect on the reaction. The extent of reaction depends on the temperature and the hydrogen partial pressure. In the absence of hydrogen no reaction occurs, but at low hydrogen partial pressures complete hydriding is possible. The rate at which zirconium hydrides depends on the temperature, the hydrogen partial pressure, and the presence of an oxide film on the metal. The rate of reaction increases with increasing temperature and hydrogen partial pressure. The presence of an oxide film, present initially on the metal or formed by low concentrations of water in the organic coolant, retards the rate of reaction.

No difference was observed between zirconium and Zircaloy-2 alloy.

Acknowledgment

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Part 2—Hydrogen Corrosion of Uranium

Abstract

Uranium was exposed to organic reactor coolants at temperatures up to 400 C under various conditions of constant hydrogen partial pressure and low water concentration. Uranium reacts with hydrogen to form uranium trihydride according to the rate law:

$$\text{rate} = k\,(P - P_D)^{2.5}$$

Where k is the rate constant, P is the partial pressure of hydrogen, and P_D is the decomposition pressure of UH_3. The presence of the organic coolant reduces the rate to an eighth of the rate in dry hydrogen. At 375 C and above, UH_3 reacts with the organic coolant to form UC and in a confined system this reaction can result in an autocatalytic destruction of uranium. 6.3.17

Introduction

ORGANIC REACTOR coolants are essentially non-corrosive to materials of nuclear reactor construction. However, in the presence of hydrogen, which is formed from pyrolytic and radiolytic decomposition of the organic fluid, both uranium and zirconium alloys are damaged. Part two of this study describes the hydrogen corrosion of uranium in organic reactor coolants.

Preliminary experiments by Bowen[1] showed that in a sealed system where hydrogen can accumulate, uranium is severely attacked in monoisoproplybiphenyl, (MIPB). Figure 1 shows a sample of uranium after exposure to MIPB for 9 days at 375 C. Maximum pressure attained was 160 psig. Figure 2 shows a sample of uranium after exposure to MIPB for 7 days at 400 C. Maximum pressure attained was 720 psig. The reaction product was identified in these cases as uranium monocarbide, UC. Uranium samples which were exposed to MIPB at 300 C in the absence of hydrogen for 3½ months, were not attacked.

Experimental

The experimental procedures were the same as those used to study the hydriding of zirconium described in Part 1. The uranium samples were approximately ½ x 1 x ⅛ inch and were etched in nitric acid prior to testing.

The extent of uranium reaction was determined by the loss in sample weight during exposure. Before the samples were weighed after exposure they were cleaned in a 10 volume percent solution of H_2SO_4 at 50 C for 30 minutes. This cleaning procedure removed most of the reaction products from the sample without causing a significant loss of metal weight. The weight loss during cleaning was about 0.25 mg/cm².

Results and Discussion

The results of these hydrogen pressure experiments with uranium in MIPB are given in Table 1. These data show that (a) at constant hydrogen pressure the corrosion rate is greatest at about 225 C and it decreases with increasing or decreasing temperature, (b) the corrosion rate increases rapidly with increasing hydrogen partial pressure, and (c) the corrosion rate increases with increasing water content in the MIPB.

The data obtained at 5 psi hydrogen are shown in Figure 3. The dashed curve was obtained from Burke's data[2, 3] for the reaction, $U + 3/2\,H_2 \rightarrow UH_3$. The curve is drawn in arbitrary units because only the shape of the curve was desired for comparison. The actual rates obtained by Burke were considerably higher than those observed here. The similarity between the temperature dependence curves for the corrosion in MIPB and the formation of UH_3 suggests that the primary corrosion reaction in MIPB is the formation of UH_3.

Johnson and Newton[3, 4] have shown that the rate of hydrogenation of uranium can be represented by the equation

$$(\text{rate}) = K(P - P_D)^{2.5}, \text{ where}$$

K = rate constant

P = hydrogen pressure

P_D = dissociation pressure of UH_3

If the corrosion reaction is controlled by the formation of UH_3 then a strong dependence on hydrogen pressure should be observed as indicated by the 5/2 power of the preceding equation. This was indeed observed. For example, at 300 C the dissociation pressure of UH_3 is 0.5 psi[3, 5, 6] and the predicted ratio of the weight losses at 5.0 and 1.0 psi hydrogen is

$$\left(\frac{5 - 0.5}{1 - 0.5}\right)^{2.5} = 240$$

The observed weight loss ratio was

$$\frac{93}{0.68} = 137.$$

At 250 C the dissociation pressure is 0.09 psi and the predicted weight loss ratio is

$$\left(\frac{5 - 0.09}{1 - 0.09}\right)^{2.5} = 67$$

The observed ratio was $\frac{285}{3.15} = 90.5$

The reaction product formed in MIPB below 375 C was identified by X-ray analysis as $\beta - UH_3$. Consequently, it was concluded that the controlling corrosion reaction for uranium in MIPB is the formation of UH_3 and is probably described by the equation,

$$(\text{corrosion rate}) = K(P - P_D)^{2.5}$$

In the preceding equation, if P is less than P_D, then no reaction can occur. At

Figure 1—Uranium in MIPB at 375 C for 9 days at 160 psig maximum pressure.

Figure 2—Uranium in MIPB at 400 C for 7 days at 720 psig maximum pressure.

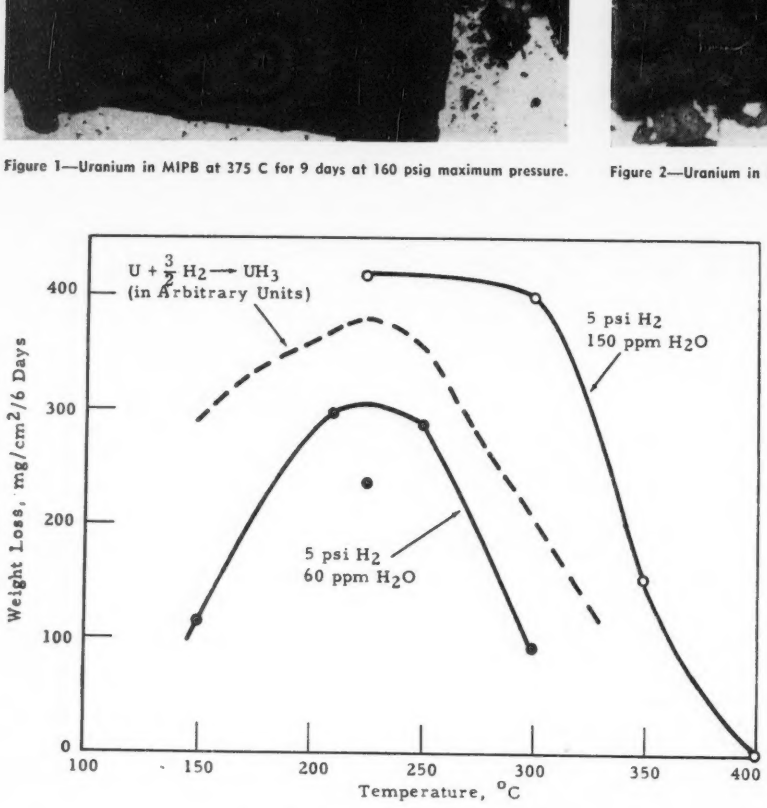

Figure 3—Corrosion of uranium in MIPB.

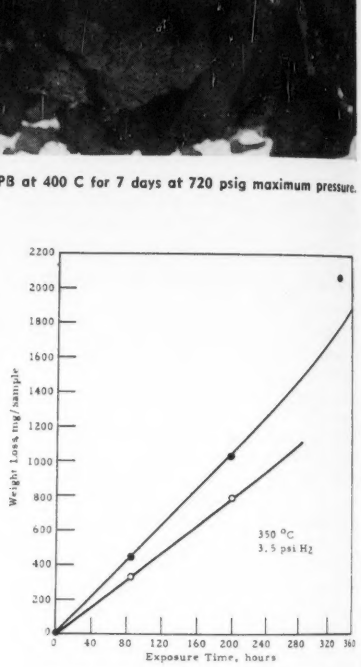

Figure 4—Corrosion of uranium in MIPB.

TABLE 1—Corrosion of Uranium in MIPB

Temperature, Degrees C	Hydrogen Partial Pressure, psi	Water Content MIPB, ppm	Weight Loss* After 6 Day Exposure, mg/cm²
400	0.3	60	0.0
400	5.0	150	0.0
350	3.5	60	11.5
350	5.0	150	154.0
300	1.0	60	0.68
300	5.0	60	93.0
300	5.0	150	401.0
250	1.0	60	3.15
250	5.0	60	285.0
225	5.0	60	232.0
225	5.0	150	416.0
210	5.0	60	297.0
150	5.0	60	114.0

* Weight losses are corrected for cleaning loss of 0.25 mg/cm².

400 C, P_D is 6.7 psi[3,5,6] and the experiments were conducted at 0.3 and 5.0 psi hydrogen pressure. No reaction was observed. A further consequence of this rate law is that since the rate is proportional to $(P - P_D)$, then at constant P the corrosion rate is also constant. To test this, samples of uranium were exposed to MIPB at 350 C and 3.5 psi hydrogen pressure. They were weighed after 84, 198, and 338 hours exposure. Since the test involved accumulating exposure on the same samples, they could not be cleaned in dilute sulfuric acid before weighing. The weight losses were fairly large, however, and the bulk of the corrosion product was nonadherent, so the error induced by not cleaning the samples was small. The results are shown in Figure 4. Constant corrosion rates were observed.

It was found that the rate of hydriding of uranium is much slower in MIPB than in dry gas under otherwise similar conditions. The data are given in Table 2. At 225 C and 5 psi hydrogen pressure the rate in MIPB was about an eighth of that in the dry gas. This result is consistent with an observation made at

Ames[3] that the rate of hydrogenation of uranium in mineral oil at 250 C was only 1 percent of the rate obtained in dry gas.

Samples of the reaction product formed in MIPB were identified by X-ray analysis. The reaction product formed at 350 C and below was identified as $\beta - UH_3$. At 375 C, and above, the reaction product formed was UC. It was concluded that at the higher temperatures the UH_3 is formed first but it rapidly reacts with the MIPB (or its decomposition products) to form UC. The following reactions occur:

1. organic $\xrightarrow[\Delta]{}$ organic + H_2
2. $U + 3/2\ H_2 \rightarrow UH_3$
3. UH_3 + organic $\rightarrow$ UC + $3/2\,H_2 + X\,H_2$

In a sealed system the hydrogenation of uranium above 375 C is autocatalytic. When the hydrogen formed in reaction No. (1) exceeds the dissociation pressure of UH_3, reactions (2) and (3) commence. The hydrogen pressure increases rapidly as a result of reaction (3) and, therefore, reaction (2) is greatly accelerated. The sample of uranium shown in Figure 2 was completely converted to UC by this process.

A few experiments were conducted in biphenyl which is considered more thermally stable than MIPB and does not have the vulnerable side-chain substitutions of MIPB. No difference was observed in reaction rates or corrosion products formed in biphenyl and MIPB.

TABLE 2—Effect of MIPB on Hydrogenation of Uranium

Temperature, Degrees C	MIPB	H_2 Pressure, psi	Weight Loss After 6 Day Exposure, mg/cm²
225	Yes	5.0	232
225	No	5.0	1775

Conclusions

Uranium reacts with hydrogen to form the compound uranium trihydride, UH_3. The rate of the reaction depends on temperature and the hydrogen partial pressure. The reaction rate is maximum at about 225 C and decreases with increasing or decreasing temperature. The reaction follows the rate law,

$$\text{rate} = k\,(P - P_D)^{2.5}$$

where k is the rate constant, P is the hydrogen partial pressure, and P_D is the decomposition pressure of UH_3. The decomposition pressure of UH_3, P_D, is a function of temperature. If the partial pressure of hydrogen is less than the decomposition pressure of UH_3 at the given temperature, no reaction occurs. When the partial pressure is greater than the decomposition pressure, the rate of reaction increases rapidly with increasing hydrogen partial pressure. At constant hydrogen partial pressure and temperature the reaction rate is constant.

The presence of the organic coolant reduces the reaction rate to an eighth of the rate in dry hydrogen. There was no difference between the pure polyphenyl biphenyl, and the aromatic substituted polyphenyl, monoisopropylbiphenyl.

Corrosion rates observed in MIPB containing 150 ppm water were somewhat higher than those in MIPB containing 60 ppm water.

At temperatures of 375 C and above, the UH_3 reacts with the organic coolant (both biphenyl and monoisopropylbiphenyl) to form uranium monocarbide, UC. In a confined system this reaction is autocatalytic, since the reaction not only liberates the hydrogen from the UH_3 but also liberates hydrogen from the reacted organic. This causes an ever-increasing hydrogen pressure and an ever-increasing rate of reaction.

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Any discussion of this article not published above will appear in the December, 1960 issue.

High Temperature Corrosion Problems In the Reduction of Nickel Copper Ores*

By R. J. LAW

Abstract

A review is given of certain high temperature corrosion problems involved in the reduction of Canadian-mined nickel copper ores. Emphasis is placed on the proper selection of materials for various pieces of mining and processing equipment. Among the pieces of equipment discussed are roasters (superimposed on reverberatory furnaces), converters, lute caps, piping, drag line conveyors, sinter machines and hot crusher rolls. Materials of construction tested include cast iron, cast 28 chromium-3 nickel, 25 chromium-12 nickel, ductile iron, 13 chromium-0 nickel, 26 chromium-46 nickel-5 tungsten, and Types 431 and 410 stainless steels. 8.10.3

Introduction

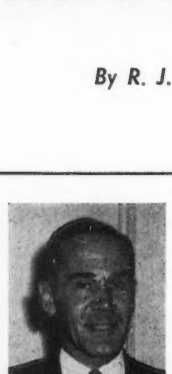
THE INTERNATIONAL Nickel Co. of Canada Ltd. plants in the Sudbury area in Ontario handle as much as 40,000 tons of ore a day. Here the ores, essentially pentlandite, chalcopyrite, and pyrrhotite, are mined, milled, and concentrated, and to a degree separated into a crude form of the final product or a mixture of products.

Copper, some of the precious metals, and a high grade iron ore are produced in the Copper Cliff works. Nickel in the form of a sinter, or more recently to some extent as a sulfide, is shipped to the nickel refinery in Port Colborne, Ontario for electrolytic refining. Fourteen elements or products are finally separated and made available in a form for commercial use. These products consist of nickel, copper, cobalt, platinum, palladium, rhodium, ruthenium, iridium, gold, silver, selenium, sulfur, tellurium, and a high grade iron ore. A large number of steps are necessary to achieve the separation of this complex list of products. Steps involved include hydro-metallurgical, pyrometallurgical, chemical, and electrolytic processing in addition to mechanical milling and separation. It can be readily imagined that there will be a multiplicity of corrosion problems encountered in an operation of this magnitude. For the purpose of this presentation a few of the problems associated with some of the high temperature operations at the Copper Cliff works will be discussed here.

Smelter Plant Operation

The Copper Cliff smelter consists of two main circuits, (a) the nickel circuit for the smelting of nickel concentrate and the production of a high grade nickel copper matte, and (b) the copper circuit for the smelting of copper concentrate and production of blister copper. An auxiliary blast furnace circuit treats direct ore and revert material.

The nickel circuit consists of seven batteries of six Nichols-Herreschoff roasters superimposed on seven reverberatory furnaces, and seventeen converters. The roasters present an interesting problem of materials selection and design. Roasters are top-fed continuously, each roaster receiving a charge amounting to around 250 tons per day of nickel concentrate filter cake mixed with sand and quartzite. Roasting is autogenous once started, although the heat from the roasting is supplemented at times to permit high throughput, by the use of fuel oil.



About the Author

R. J. LAW is affiliated with the Development and Research Division of Inco of Canada Ltd. He was associated formerly with Ferro Enamels (Canada) Ltd. He has a B.S. in chemical engineering from McGill University and is a member of NACE, ASM and Chemical Institute of Canada.

Each roaster consists of a ½″ steel shell 21′-6″ in diameter, 38′-8″ high, strengthened by ⅝″ steel bands 8″ wide. Each such roaster has eleven hearths. The shell and the hearths are lined with alumina fire clay brick.

The wet charge is fed onto the top hearth where it is essentially dried before descending step by step to the ten lower or interior hearths. Flow of the charge is guided by rabble arms and alternately directed towards the hearth center and periphery in successive hearths by the location of ports and the angle to which rabble blades are set. Rabble arms are attached to a cast iron central column built in sections, which rests on a step bearing and is revolved at 1½ to 2 rpm by a spider geared to a speed reducer driven by a 20 hp variable speed motor.

Air is supplied by eight 23,000 cfm fans to a header from which ducts run to the central shaft of each roaster. The air cools all rabble arms on the interior hearths and the central shaft, and is conducted to the outside of the roaster building. Some air is allowed to escape through openings in the rabble arms and shaft to aid combustion. Roaster shells are enclosed by an insulated sheet steel casing approximately 4 inches from the shell leaving an annular space open at the bottom of the roaster to permit cooling air to rise around the shell. The air becomes heated and is drawn off at the top through headers which discharge outside of the building, thus vastly improving working conditions in the building.

The roasted concentrate or calcine is discharged from the bottom hearth at a temperature of 1300-1500 F into four 12 ton brick lined surge bins which serve each battery of six roasters. The calcine then flows by gravity through 12 inch cast iron pipes, cast with 10 gauge steel liners, to drag conveyors. These conveyors carry the calcine over the reverberatory furnaces.

Materials of Construction

Initially, most of the metallic components in the roasters consisted of cast iron. While this material gave reasonably good performance, experimentation with other materials has been carried on. The wet charge is fed onto the top hearth, and is completely dried and ready for ignition by the time its travel on the third hearth has been completed. There is of course ample heat for drying rising from the lower hearths.

Maximum temperature, around 1700 F, is encountered on hearth Nos. four, five, and six. Below this there is less active combustion, and some reduction in temperature occurs so that calcline is discharged from the bottom hearth at 1300-1500 F. However, the calcined material on the lower hearths is harder and more gritty and is therefore more abrasive. For some years now, cast 28 chromium 3 nickel rabble blades have been used from the fourth hearth down, where cast iron was unequal to the high temperature and abrasion. For the most abrasive sections, from hearths eight to eleven, these alloy blades are fitted with silicon carbide inserts on the wearing edges.

Rabble arms are 104″ long x 6″ wide x 8″ high tapering down to 4″ at the outer tip. They have a ¾″ wall tapering down to ⅝″, and have a typical weight of 443 pounds. Below the dryer hearths, arms are air cooled, as is the cast iron center column or drum section which supports the arms. Drum sections of the column have been no problem, but even with air cooling, replacement of cast iron rabble arms is fairly high (average calculated life is 9.5 months). A trial of 25 chromium-12 nickel rabble arms is currently being planned.

Another economical application for the 28 chromium-3 nickel alloy appears to have been found in what is called the lute caps, or seals, over joints in the

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drum section where cast iron lasts about 24 months. Average life of alloy caps has been 4.7 years, and in addition, a better seal is provided.

The 12″ diameter steel lined cast iron pipe through which calcine flows to the conveyor lasts on the average for about six years. A trial with as-cast ductile cast iron was initiated about six years ago with the installation of 24 sections of pipe 12″ diameter by 7′-4″ and 8′-4″ long. Calcine flows through the pipe at about 800 F. After 32 months these sections of pipe were found to be in excellent condition, and additional sections have been installed. At the present time, after six years service, there have been no failures of ductile iron pipe. Pipe of this composition has been selected as the standard material for this service, and will be installed in place of cast iron steel lined pipe as replacements are needed.

The drag line conveyor which carries the roaster calcine over to the reverberatory furnaces is exposed to hot, abrasive conditions which are quite severe. There are two conveyors to each furnace, located above and along either side, so that calcine is fed to the furnace at the side walls. By this manner of feeding, the charge is banked on either side along the length of the furnace, providing a measure of protection to the side walls.

The conveyor liners are cast iron 2′-11½″ long x 1′-7/16″ wide and 1¼″ thick, with 5″ high x ⅜″ thick side boards. Openings in the center of each liner permit calcine to discharge into fettling pipes through which the feed enters the furnace by gravity. At the point of entry to the conveyor, calcine is at a temperature of 700-800 F. Service life of cast iron liners ranges from 125 to 175 days, failure resulting from wear or cracking in the region of ports.

A number of alternatives have been investigated. A mottled iron, and nickel chromium white iron proved to be inferior to cast iron, lasting 85 days and 111 days respectively, failure of the latter being due to heat cracking. Ductile iron from several sources was tried with variable results. The best of these was a 60-45-10 grade, which lasted 225 days, eventual failure being due to wear only. This performance was considered to be equivalent to cast iron as regards cost. A composition is on trial currently which looks very promising. This is a white cast iron containing 0.5 percent molybdenum and a small amount of tellurium. After 12 months, test liners were still in service. Several 28 chromium-3 nickel liners were tried. One failed by cracking after 190 days and the remaining two stood up for 493 days. It appears unlikely that economical benefit would be obtained with a liner of this high alloy composition. However, this alloy is giving economical performance as fettling pipe sleeves, where it gives an average life of 383 days as compared with 165 days for steel.

Reverberatory furnaces are 110′ long x 24′ wide, inside dimensions, and are fired from one end by four burners using powered coal fuel at the rate of 180 to 200 tons per day. There are some interesting features in the design of the reverberatory furnaces which have greatly extended the periods of operation between major shutdowns for repairs. In place of sprung arch silica brick roofs used originally, unburned chemically bonded magnesite brick roofs are now employed. This type of roof has the advantage of permitting roof repairs to be made without shutting down the furnace. In contrast to this, the sprung roof gave an average life of 90 days.

In a six year period following the adoption of the suspended roof on all seven furnaces, it is estimated that the loss of over 1000 furnace days has been avoided. Roof bricks are suspended from cross rods bent to follow the contour of the shoulders of the roof. Each unit is 12″ x 12″ and consists of two bricks which engage a "T" on the end of the hanger rod; the two bricks are then encased in a light gauge steel "can." Roof repairs can be made by "hotpatching" with this "canned" brick arrangement. After installation, the steel tends to fuse to the adjacent unit, giving a fairly good seal. Heat losses are known to be higher with this type of roof, but this is a small percentage of the total heat input. An average of 2000 sq. ft. of roof brick per furnace per year is replaced, mostly within 60 feet of the firing end, without shutting down the furnace.

Hangers

Roof brick hangers are ⅝″ diameter by 10″ long, hooked at one end to engage the supporting cross rods. They have a "T" at the bottom to engage the roof brick. Regular practice is to use cast iron hangers (they normally outlast the roof brick which burns back to the "T" in an average of 3.5 months). However, hangers located in roof areas under flue dust screws and drag conveyors are insulated by spillage and thus become overheated and occasionally suffer premature failure. A number of cast heat resisting alloy hangers were tried in a study of the problem. Alloys tested and the results obtained for six of each were as follows:

28 Cr- 8 Ni—All six removed after 92 days.
28 Cr- 3 Ni—Three removed after 46 days. Three removed after 7 months.
25 Cr-12 Ni—Three removed after 45 days. Three removed after 7 months.
13 Cr- 0 Ni—Three removed after 51 days. Three removed after 7 months.

Test hangers showed signs of softening and melting at the base and it was concluded that they offered no significant improvement over cast iron, particularly on a cost comparison basis. An effort is made to minimize the problem by keeping the roof clean. Spillage of calcine has been reduced considerably by the use of the 28 chromium-3 nickel sleeves in the fettling pipes mentioned earlier. Steel in this location burned through rapidly, permitting excessive spillage.

Coal burner nozzles on the reverberatory furnaces are exposed to high temperature from radiated heat, and standard practice is to use water cooled copper tipped cast iron. This gives fairly satisfactory service. Nozzles of 28 chromium-3 nickel, without water cooling, lasted only 16 days. A 26 chromium-46 nickel-5 tungsten alloy was still in good condition after 137 days.

Another feature in the reverberatory furnace design employs large "canned" brick for the upper side walls. Lower side walls are magnesite brick up to the top of the banked bed of calcine. Above this level side walls are burned out much more rapidly. Side wall "cans" can be replaced and repairs made without undue inconvenience, and usually without shutting down the furnace. A "can" consists of a sheet steel case 3′ x 1′-6″ x 8″ filled with a tamped basic refractory mix, and can be hung in position from overhead supporting members.

Since suspended roof and upper side walls have been incorporated into the reverberatory furnace design, major shut downs are required only about once every five years for each furnace.

The reverberatory furnace discharge is a matte containing 13 percent copper nickel. This is tapped through magnesite block tapping holes at the side near the front end of the furnace. It then flows through a launder to a 185 cu. ft. capacity cast steel ladle on a transfer car in a tunnel which parallels the furnace and leads to the converter building. Slag containing 36 percent SiO_2, 37 percent Fe and 7 percent Al_2O_3 is skimmed at the front wall of the furnace into 215 cu. ft. cast steel pots mounted on cars and transported to the slag dump.

Nickel Circuit Converters

There are 17 converters in the nickel circuit which are situated in a row opposite the burner end of the reverberatory furnaces, and separated from them by a crane aisle 66′ wide. Converters are of the Pierce-Smith type, 13′ x 35′, with hard burned chrome magnesite brick linings and having, in most cases, 48 tuyeres for admission of air. Reverberatory and blast furnace matte is ladled into converters along with a flux containing a 60-40 mixture of low grade ore and quartzite. After charging, the converter is rotated so that the mouth is positioned at the top and the converter hood is lowered into place. The hood fits tightly over the mouth when the converter is in the blowing position, to avoid loss by splashing of the molten charge. In the converter operation, the furnace matte is blown to a 75 percent copper nickel matte called Bessemer matte. Slag containing 26.5 percent SiO_2 is skimmed into 225 cu. ft. capacity ladles for return to the reverberatory furnaces. Matte is then poured into steel ladles and transported molten to the casting building.

Such metal components as are involved in the converters offer little application for heat resistant alloys. The interiors of converter hoods are exposed to high temperatures by radiated heat, to very hot sulfurous gases, and to metal washing by molten metal splash. Cast iron liners are used and last about as long as 28 chromium-3 nickel, and 25

chromium-12 nickel alloys which have been tried. However, Type 410 stainless steel bolts are found to perform to advantage over steel bolts, and are used for fastening the liners.

Type 431 stainless steel tuyeres punch bars, ¾″ diameter, were placed on trial on one converter. Bar consumption averaged one bar per tuyere per charge. This represented no advantage for the alloy over mild steel bars.

Ductile iron has been adopted for the actuating valve lever and tuyere adapter originally made from cast steel. Grey cast iron was too brittle in this service; ductile cast iron performed, however, at a lower unit cost than steel. Pneumatically operated punching machines are in service on nickel converters and the ductile iron components in each machine weighed 33 pounds. An extremely abrasive service is encountered with the flux guns used to introduce the flux to the converter charge. Nickel-chromium martensitic white cast iron is used and has a 19 day life as opposed to the 9 day life of an unalloyed cast iron formerly used.

Some problems have been encountered due to the high temperatures and abrasive conditions in some sections of the gas handling system. Temperatures remain well above the dew point so that condensate corrosion does not present a problem. In one set of tests, five 42″ diameter ductile cast iron elbows, each weighing 2600 pounds, were used in the gas off-take line from the converters. In this service the elbows are exposed to gas at an average temperature of 1400 F. A cast iron with an average life of 2.8 years normally is used. Failures occur as a result of cracking due to expansion and contraction stresses. Service life of ductile iron elbows was four years, which was not quite enough to economically justify its choice over the standard unalloyed cast iron.

In the copper converter gas line, where gas temperature is down to around 800 F, ductile cast iron has successfully replaced steel lined cast iron pipe. For trial purposes one ductile iron valve box 2′-8″ x 3′-3″ x 3′-4″ x 1″ thick and nine sections of pipe, 48″ diameter x 6′-5″ long x 1″ thick were installed. After 3.5 years service the test members were still in excellent condition. Although seven years will be required to finally prove its superiority economically, the application of ductile cast iron has been approved tentatively. It is the material that is being used for replacements as they are required.

The 500′ concrete chimney was capped with a cast CF-12M (19 percent chromium, 11 percent nickel, 2 to 3 percent molybdenum, stainless steel) cap in 1949. This has prevented deterioration of the upper part of the chimney which previously required periodic repairs. Similar caps have since been installed on four other chimneys. An inspection of the first cap eight years after its installation showed it to be in excellent condition. The corrosive conditions here are of course the result of an aqueous acid condensate rather than high temperature conditions.

Sintering of Nickel

The final step in the nickel circuit involves a sintering operation which converts nickel sulfide to the oxide. But first a brief description of the process between the converters and the sintering operation might be in order for the sake of continuity. The molten Bessemer matte is cast into 25-ton moulds for controlled slow cooling to promote formation of relatively large discrete crystals. After crushing and grinding, magnetic separation and froth flotation serve to separate the copper and nickel constituents.

There are five sinter machines in the plant, each 65′ long by about 5′ wide. Feed is deposited on an endless travelling hearth which reverses direction of travel over large sprocket drive wheels at either end of the machine. The hearth consists of a chain of pallets 48″ wide x 24″ long, with side boards about 12″ high. Fastened to these pallets are grate bars 7¾″ x 20⅝″ x 1⅛″ thick with herring bone slots. A thin bed of oversize sinter is deposited on the hearth and feed is then fed to a depth of about 12″ by means of a swing spout. The pallets travel on wheels on a stationary track. Immediately after loading they enter a 6′ long oil fired muffle. Travel through the firing zone takes about 2½ minutes, which is sufficient time to ignite the bed. This bed continues to burn for the remainder of the travel, by which time conversion to oxide is complete.

A vacuum under the hearth draws flame down through the bed and draws off SO_2 gas which is exhausted to the stack. The complete cycle requires 40 minutes, half of which is devoted to the combustion process. Hot sinter at 1400 F is dumped directly at the discharge end sprocket wheel into crusher rolls. Crushed sinter is subsequently reduced in size to the nickel oxide product of the Copper Cliff operation. It is then shipped to the nickel refinery in Port Colborne, where it is electrolytically refined to pure nickel. A substantial tonnage is shipped directly to steel mills in the form of sinter. By a recent process development, electrolytic nickel is now produced by direct electrorefining of nickel sulfide. A part of the Copper Cliff product now by-passes the sintering operation.

Grate bars and pallets on the sinter machines have been the source of much trouble. Cast iron pallets, 65 on each machine, are used. Side boards are subjected to some flame impingement during the brief travel through the muffle. It is in this section that earliest deterioration occurs. Average total life of cast iron pallets, with some intermediate repairs, is 15.5 months, warpage and cracking being the cause of final discard. An early trial with ductile cast iron was unsuccessful but a second trial is now in progress.

There are six grate bars on each pallet, or 390 per machine. Cast iron bars used initially had an average life of 60 days. A test program was initiated in which several compositions of ductile cast iron and various heat resistant chromium nickel alloys were studied. Ductile iron showed little promise in the early tests and was omitted from further testing. All of the high alloy bars performed substantially better than cast iron, particularly the 25 chromium-12 nickel alloy. Increasing numbers of test bars in this alloy were placed on test, and finally half a unit was so equipped. The average life of 198 of these grate bars was 579 days (or approximately ten times that of cast iron). Two of the sinter machines are now equipped completely with 25-12 grate bars.

Hot crusher rolls also have been a source of considerable trouble. Rolls are cast in a low alloy high strength steel and are surfaced with pyramidal cobbles. Roll dimensions are 3′ diameter by 3′-2″ long. In contact with the hot sinter the roll temperature reaches about 1000 F. Life of rolls has been variable with failures occurring as a result of cobbles breaking and rolls cracking. Not infrequently, broken grate bars or pallet sections enter the crusher rolls, and this makes the service even more rugged. A number of low alloy compositions have been tried. The most serviceable has been a 0.60 carbon, 0.15 nickel, 0.96 chromium, 0.42 molybdenum with a hardness of 340 Brinell. A test roll was still in service after 65 days, which warranted approval of this alloy. It now gives an average life of four years.

Thanks are due to Dr. G. A. Harcourt and Mr. R. B. McIntosh of Inco, Copper Cliff, for their assistance in providing information and test data used in preparing this discussion.

Any discussion of this article not published above will appear in the December, 1960 issue.

Cathodic Protection of Prestressed Concrete Pipe*

By M. UNZ

Abstract

Prestressed concrete pipe has the reinforcement either partly embedded in the concrete core or totally placed over the core under a cement mortar cover. Lines of the latter type are bonded at the steel joint rings to provide for electrical continuity. With the aid of insulating joints at junction points, adequate control of galvanic currents is ensured. The lines also have the advantage of being suitable for cathodic protection.

From an analysis of the line constants it follows that higher drainage current densities are required for this kind of pipe than in bituminous coated systems. The feeding points must be spaced closer due to stronger attenuation. Nevertheless cathodic protection can be economically applied under corrosive conditions. A field example has been described; constructional details also are given and design methods numerically discussed. 5.2.1

Introduction

PRESTRESSED concrete lines are kept safe from exterior corrosion attack by preventive planning. The cement mortar used for the coating produces on the reinforcing steel a potential 0.5 volt more noble than that of bituminous coated pipe. The cement also exhibits self-healing properties. In low resistivity soil the insulation resistance of the mortar can be improved by additional bituminous coating. Circulating currents are reduced by means of insulating joints.

In the case of unforeseen corrosion danger, cathodic protection is applicable to concrete lines which are electrically continuous. Efficient protection from exterior corrosion attack is important because of small cross-sections of the high tensile reinforcement. Stress corrosion can also be prevented or brought to a halt by electrical drainage.[1]

Careful design of cathodic protection circuits is required to meet the special features of prestressed concrete pipe.

Electrical Continuity

Types of Pipe

The degree of electrical continuity affects the anticorrosive properties of a line. An all welded steel line, for example, is exposed to the accumulative action of galvanic currents over its whole length, whereas reinforced drainage pipe with concrete bell and spigot joints is practically immune to the effects of long line currents. In prestressed concrete pipe three intermediate types can be distinguished regarding their electrical continuity (see Figure 1). They are as follows:

(a) Pipe with steel joint rings for which the entire reinforcement is placed over the core and under cement mortar coating.

(b) Pipe with steel joint rings for which the axial reinforcement or a steel cylinder are deeply embedded in the concrete core and the prestressing wire wrapped over the periphery of the core under a cement mortar cover.

(c) Pipe with non-metallic joints. The entire reinforcement in such cases is self-contained and insulated in each pipe unit.

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About the Author

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The steel joint rings of types (a) and (b), when developed as a bell- and spigot joint with rubber ring gasket, are for mechanical reasons supposed to give metallic contact between the pipe units. Even though a conductive greasing compound is applied for assembly (in this case a soap of about 50 ohm-cm resistivity and pH ÷ 10), electrically this contact cannot be relied upon, as dirt particles penetrate in the course of construction.

In pipe of type (a), with the entire reinforcement under a mortar cover, such accidental lack of contact may cause difficulties. Axial currents built up along a continuous section of the line are forced to bypass the high resistance joint through the ground. Potential differences of 100 mV or more are common over such joints. Axial currents up to 6 amps have been measured on the lines of this company. As a result serious corrosion must develop at the discharge points. In addition to this, the erratic performance of some of the joints makes a systematic investigation of the galvanic conditions impossible.

Bonding of Type (a) Pipe

To improve these conditions the writer recommends electrical bonding of type (a) pipe, combined with the provision of insulating joints at key points. The natural performance of the line is thus brought under control and cathodic protection can be installed whenever required. The continuity bonds consist of a steel flat radially welded on to each of the end rings, with an interconnecting copper link to secure the flexibility required for eventual changes of the pipe alignment.

The flat copper strip shown in Figure 2a is brazed to the steel flats, whereas the stranded copper cable (Figure 2b), is attached by a thermit joint. When the necessity arises to weld the steel plates onto an assembled line, care must be taken not to damage the rubber gaskets. Only electric welding is then permissible and temperatures must be checked on test pipes.

For exterior insulation, the bond as well as the adjacent concrete surfaces are coated with a bituminous primer. A hollow precast block is placed over the bond and filled with hot bitumen. Measuring leads or drainage feeder cables are carried out from these bonds, if required.

A bonded line evidently must be continuous in all its components. Intermediate steel sections shall be bonded to the concrete pipes unless insulating joints are required. Wire mesh or rods used for mortar reinforcement are to be welded to the main steel body. Adequate thickness of the mortar cover must be provided over all parts of the reinforcement,

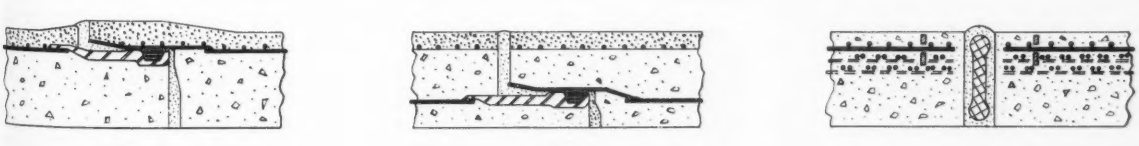

Figure 1—Electrical continuity of prestressed concrete pipe. (Diagrammatic cross-sections.) (a) With steel joint rings; reinforcement over the core. (b) With steel joint rings; reinforcement partly embedded in core. (c) With non metallic joints.

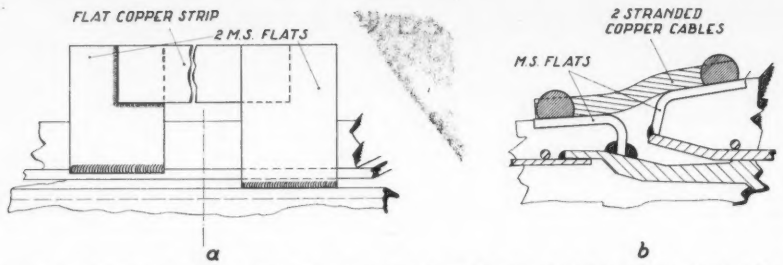

Figure 2—Continuity bonds. (a) With brazed copper strip—axial view. (b) With thermit welded cable side view.

in order to secure a standard value of the leakage resistance.

Type (b) Pipe

The pipe with steel joint rings and an embedded cylinder (Figure 1b), reduces the danger of axial corrosion currents. Its cylinder is covered by more than two inches of concrete core, so as to prevent the penetration of galvanic currents. The prestressing coils over the core are electrically insulated from the cylinder as well as from the coils of the adjacent pipe units. For this type of pipe no bonding of the joints is required.

Resistance bonding for coordination with other systems is not advisable. Cathodic protection cannot be applied. The replacement of the greasing soap used at present for the joints, by some non-conductive compound would be of considerable advantage. The new greasing medium should be of alkaline character and fully compatible with the synthetic rubber gaskets.

For pipe with steel end rings, types (a) and (b), insulating joints are required betwen line sections of different characteristic as well as for all bituminous coated tappings.[2] At the high natural potential differences existing between different line sections the current intensities depend primarily on the insulation resistance. Routine insulation measurements are therefore required on the joints, especially those placed underground.

Type (c) Pipe

Perfect inherent protection from accumulative galvanic effects is attained on pipe with non-metallic joints, such as that covered by the Freyssinet patents (Figure 1c). The corrosion currents are there limited to the local galvanic circuits of every single pipe unit. No insulating joints are required and coordination problems do not arise owing to the complete lack of continuity.

Line Constants

Axial Resistance

The axial resistance of a prestressed concrete line with steel joint rings is made up of the resistance of the individual pipe units, the resultant joint resistance and the fringing effect caused by the congestion of current lines on each side of a joint. Owing to the relatively short length of the pipe units, at internal diameters ranging between 20 and 66 inches, each of the resistance components must be separately computed and correlated with experimental results. The following practical example illustrates the method of calculation.

Net Pipe Resistance. The axial resistance of a 48-inch line of cylinder type pipe will be computed. The pipe consists of a mild steel cylinder with joint rings over the concrete core and a high tensile steel winding around it. The data of the cylinder are as follows:

Diameter, D,	137.1 cm;
Length, L,	489 cm;
Mean thickness, t_s,	0.17 cm.

Whereby the mean thickness includes an estimated allowance for the joint rings and the steel wire winding. With a mean specific resistivity of the steel $\rho_s = 14 \times 10^{-6}$ ohm.cm for parallel current paths, the axial resistance of one pipe unit

$$R'_{sp} = \frac{489 \times 14 \times 10^{-6}}{137.1 \times \pi \times 0.17} = 93.4 \times 10^{-6} \text{ ohm/pipe.}$$

This value reduced to the length of one meter gives the theoretical axial resistance for an all welded line of uniform cross-section

$$R'_s = 19.1 \times 10^{-6} \text{ ohm/m.}$$

Joint Resistance. The joint resistance comprises the continuity bonds shunted by the original contact resistance of the joint rings. The resistance of a bond as shown in Figure 2b can be readily calculated. Here it amounts to

$$R_{sb} = 45 \times 10^{-6} \text{ ohm/bond.}$$

The contact resistance of a bell and spigot joint, such as in the "Lock-Joint" system, theoretically consists of the narrow tangent surface between two cylinders of somewhat different diameters. The balance of the joint periphery is assumed to be of electrolytic conductance through patches of the greasing compound. The current flow through the greasing medium can, however, be neglected owing to the polarization potentials developing there. As the width and the location of the metallic contact faces depend on the alignment of the pipe as well as several other random factors, the joint resistance can only be estimated.

Fringing Effect. The fringing effect caused by congestion of the axial current lines which were diverted towards a continuity bond, is amenable to calculation (Figure 3 and Appendix 1). Let D denote the diameter of the cylinder and c the peripheral width of the bond welded on to the joint ring. The increase of the axial resistance due to fringing is equivalent to an extension of the cylinder length by

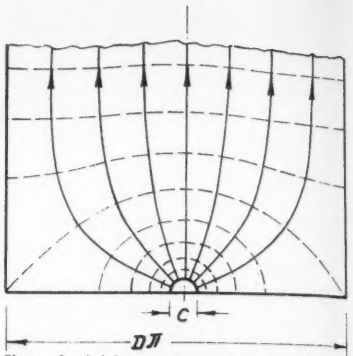

Figure 3—Axial current spreading into the steel cylinder from a continuity bond (shown on development of cylinder surface).

$$\Delta L = D \ln \frac{D}{c} \qquad (1)$$

for each pipe end. With c = 10 cm in the example assumed above, and the joint ring contact resistance assumed very large, the total apparent increase of the pipe length is

$$2\Delta L = 2 \times 137 \ln \frac{137}{10} = 715 \text{ cm,}$$

corresponding with a percentage increase of the pipe resistance by

$$\frac{2\Delta L}{L} \times 100 = 146\%.$$

For purposes of practical computation two extreme cases shall be assumed (Figure 4).

a 1) The contact surface between joint rings coincides with the bond.

b) The contact surface is diametrically opposite to the bond.

Lack of contact, as indicated in Figure 4 under (a 2), is with respect to the fringing effect identical with case (a 1). In view of the customary pipe laying procedure, case (b) appears to be the most probable on straight line sections. For the minimum value to be considered in this discussion, the contact resistance is summarily asumed not to be lower than the bond resistance. The peripheral width of the contact area is assumed to be equal to that of the bonding flats.

In order to obtain in the present example the fringing resistance for case (b), substitute in the fraction of equation (1) the value D/2 for the diameter D (see Appendix 1)

$$2\Delta L = 2 \times 137 \ln \frac{137}{2 \times 10} \text{ (cm),}$$

wherefrom follows the percentage increase of resistance

$$\frac{2\Delta L}{L} \times 100 = 107\%.$$

This is the smallest fringing resistance to be expected.

Summing up, the maximum resistance is obtained in case (a 2) and the minimum

TABLE 1—Resistance Values

Property	(a2) max., 10^{-6} ohm	(b) min., 10^{-6} ohm
Parallel paths resistance, R'_{sp},	93.4	93.4
Fringing resistance, $(2\Delta L)/L \cdot R'_{sp}$,	136.3	100.0
Bond and Contact resistance	45.0	22.5
Total per pipe, R_{sp},	274.7	215.9
Total per meter, R_s,	56.2	44.1

in case (b) per one pipe, as shown in Table 1.

From Table 1 data follows the resistance factor, F, for the above line. The factor is given by the ratio of the actually measurable to the theoretically assumed net resistance of the steel cylinder,

$$F = R_s/R'_s. \qquad (2)$$

Provided that all bonds are in good working order, it lies within the range

$$F = 2.3 \text{ to } 2.9.$$

Values of Resistance Factor. If the width of the bonding strip varies with the diameter D so as to leave the ratio D/c constant, the fringing factor $(2\Delta L)/L$ linearily increases with D. With respect to the components of the total resistance it will be found that for constant cylinder thickness t_s, the parallel paths resistance R'_{sp} inversely decreases with D; the fringing resistance remains unaltered at a constant ratio D/c, and the approximate bond resistance also inversely decreases with D. Consequently, the resulting resistance factor, F, is bound to increase with rising diameter D. In this case the range of resistance factors for a 24 inch and a 66 inch internal diameter line is given by F = 1.8 to 2.2 and 2.7 to 3.5 respectively.

The definite value of the line resistance R_s, must be found empirically by measurements on site. It varies within the above mentioned limits, depending on construction methods and topographical conditions. Still higher line resistance may be found on lines with badly fitted bonds. Direct current apparatus with pole commutation is suitable for the axial resistance measurements. When AC methods are applied, the frequency should not exceed 50 cps, in order to reduce skin effects in the steel reinforcement.

It should be noted that the axial resistance of prestressed concrete lines is much higher than that of equivalent, electrically continuous steel lines of the same diameter. This is caused by the smaller amount of steel incorporated in prestressed pipe as well as the large number of joints with their high fringing resistances.

Leakage Resistance

The decrease of pipe to soil potential caused by the flow of drainage current comprises polarization voltages and IR voltage drops across the leakage resistance. The polarization voltage is usually eliminated by suitable measuring technique. The IR component of the leakage resistance consists of the coating resistance R_c and the spreading resistance in the surrounding medium R_m

$$R_L = R_c + R_m. \qquad (3)$$

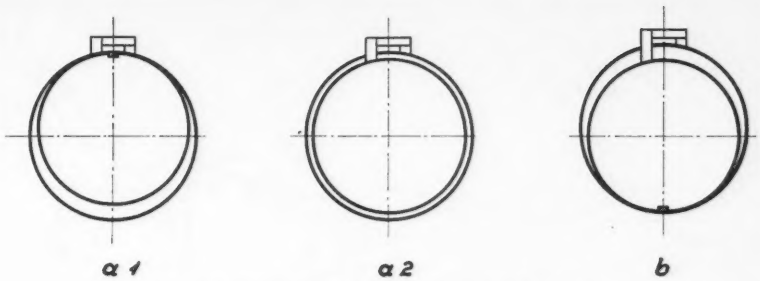

Figure 4—Contact faces between joint rings—typical location.

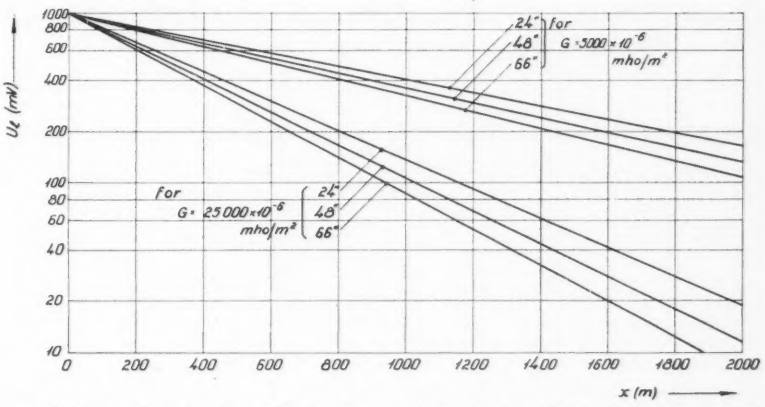

Figure 5—Attenuation profiles for cylinder type prestressed concrete lines of infinite length, with continuity bonding.

The Coating Resistance. For relatively small thickness of the coating, t_c, the coating resistance, for one meter of axial length, is given by

$$R_c = \frac{t_c}{(D + t_c)\,\pi \times 100} \cdot \rho_c \text{ (ohm.m)}, \qquad (4)$$

where D denotes the diameter of the steel cylinder in meters and ρ_c the coating resistivity in ohm.cm. For design purposes the specific conductance G per square meter of the coating is often considered, instead of the unit coating resistance,

$$G = \frac{100}{\rho_c} \cdot \frac{1}{t_c} \left(\frac{\text{mho}}{\text{m}^2}\right), \qquad (5)$$

or with reference to (4)

$$G = \frac{1}{R_c \times (D + t_c)\,\pi} \left(\frac{\text{mho}}{\text{m}^2}\right). \qquad (6)$$

Numerically the coating conductance varies with the mortar quality, the coating thickness, humidity and resistivity of the adjacent soil. The unit conductance values for ¾ inch thick cement mortar coating on nonembedded cylinder type pipe (Figure 1a), normally vary between

$$G = 3000 \times 10^{-6} \text{ and } 30{,}000 \times 10^{-6} \text{ mho/m}^2.$$

The Spreading Resistance. When determining the protective voltage in electrical drainage systems, the spreading resistance can be incorporated only as far as the current tubes of the galvanic field coincide with those of the impressed system. On cement coated lines the polarity of the galvanic zones may often change within a few feet due to different composition of the coating, while the impressed current source is usually located hundreds of feet away. As a result the current tubes of the two fields can be assumed to be identical only in the immediate vicinity of the line.

The reference cell must, therefore, be placed over the line axis. This has also the advantage that stray ground potentials are automatically eliminated. In the vicinity of insulating joints the reference cell should be kept at an axial distance of not less than 30 ft away from the joint, in order to reduce the effects of local shunt currents.

At the large diameters of concrete pipe the spreading resistance, R_m, need not be separately determined. With the half-cell placed over the line, the spreading resistance does not exceed 10 percent of the total leakage resistance, R_L, for soil resistivities up to 1000 ohm.cm.

Attenuation Constants

The high axial resistance of prestressed concrete lines combined with low leakage resistance markedly increase the attenuation constant. The dependence of the line constants on the pipe diameter

Figure 6—Thirty-six-inch prestressed concrete line SA-31, Points 3 to 140 (Layout).

TABLE 2—Line Constants for Cylinder Type Prestressed Concrete Pipe With Continuity Bonding

Pipe Nominal Diameter Inches	R_s 10^{-6} x ohm/m	For G = 25 000 x 10^{-6} mho/m²			For G = 5 000 x 10^{-6} mho/m²		
		R_L ohm.m	α 1/m	R_k ohm	R_L ohm.m	α 1/m	R_k ohm
24	76.2	19.5	0.00198	0.0385	93.9	0.000902	0.0845
48	49.4	9.8	0.00224	0.0220	47.0	0.00102	0.0482
66	42.8	7.1	0.00246	0.0174	34.0	0.00112	0.0382

is also different from that on steel lines. This is evident from the examples listed in Table 2. The data of bonded, non-embedded cylinder type pipe (Figure 1a), have therein been compared for 24, 48 and 66 inch inner diameter. The mean thickness of the cylinder has been assumed approximately the same as for the previously described 48 inch pipe. The mortar coating is 2 cm thick. The lines are bonded in accordance with Figure 2b.

The attenuation constants shown in the table have been obtained from

$$\alpha = \sqrt{\frac{R_s}{R_L}} \left(\frac{1}{m}\right). \qquad (7)$$

They range between $\alpha = 0.9 \times 10^{-3}$ and 2.5×10^{-2} 1/m. For constant thickness of the steel cylinder t_s, the value of α does not vary with the pipe diameter but for the axial resistance factor F. This can be verified by taking for R_L an equivalent coating resistance R'_c and substituting the respective values of R_s and R_c (6) in equation (7)

$$\alpha = \sqrt{\frac{\rho_s G}{t_s}} \left(\frac{1}{m}\right). \qquad (8)$$

The characteristic resistances R_k have been calculated for a semi-infinite line

$$R_k = \sqrt{R_s \cdot R_L} \text{ (ohm)}. \qquad (9)$$

For constant cylinder thickness, the resistance R_k is inversely proportional to the pipe diameter and increases with the root of the axial resistance factor

$$R_k = \frac{\sqrt{F}}{D\sqrt{\pi}} \cdot \sqrt{\frac{\rho_s}{t_s \cdot G}} \text{ (ohm)}. \qquad (10)$$

Referring to the examples in Table 2 it is seen that for a voltage $U_{LO} = 1$ volt at the drainage point, the 24 inch line would take a current of $I_1 = U_{LO}/R_k$ on each side (namely, 26 amp. at G = 25,000 × 10^{-6} mho/m² or 11.8 amp. at G = 5000 × 10^{-6} mho/m²). The drainage currents for one side of the 66 inch line would be 57.5 amp. and 26.2 amp. respectively.

The attenuation curves in Figure 5 show the IR component of the leakage voltage on lines of infinite length corresponding with Table 2

$$U_L = U_{LO}\, e^{-\alpha x}. \qquad (11)$$

Therein U_{LO} denotes the voltage at the drainage point, x = 0, in the example assumed at 1000 mV. On the 24 inch line the voltage would drop at a distance of x = 1000 m to U_L = 138 mV at G = 25,000 × 10^{-6} mho/m² and to U_L = 406 mV at G = 5000 × 10^{-6} mho/m². On the 66 inch line the respective voltages would be 85.1 mV and 327 mV.

For a comparison, under similar conditions, consider two welded steel lines of 24 and 66 inch inside diameter, with bituminous coating of a unit conductivity G = 1000 × 10^{-6} mho/m². The 24 inch line of ¼ inch wall thickness, would render a voltage U_L = 862 mV, while the voltage on the 66 inch-⅜ inch line would be 886 mV. The potential drops on the steel lines are therewith only 1/8.0 to 1/4.3 of the drop on the respective prestressed concrete lines. This outstanding difference should be borne in mind, when discussing the performance of concrete pipe.

Field Example

Line Data

Impressed current measurements were made on a 1400 meter section of line, SA-31, between the pump station and point 140 (Figure 6). The line consisted of 36 inch prestressed concrete pipe of the non-embedded cylinder type, with ¾ inch cement mortar coating. It was laid in highly corrosive soil, at one meter depth to top of pipe, except for a 270 meter section, where the pipe had to be raised above the ground surface due to high groundwater. This part of the line was covered by an embankment. The line was bonded across the pipe joints and provided with insulating flanges at the pump station and at point 140. All bituminous coated components including blow-offs and air-valves, were also fitted with insulating joints.

Ground resistivities, measured on water saturated samples, varied between ρ_m = 45 and 220 ohm.cm (Figure 7b). It was a saline soil with sulfate contents up to 7000 ppm. The actual ground resistivities on site depended on the water contents of the soil. In the vicinity of the fish ponds, points 70 to 140, corresponding in the graph with the abscissae x = 700 to 1400 meters, two sections of the line reached the water table. In other parts the pipe lay closely above it.

The drainage circuit was fed from the power network. It was connected to the line at point 16 near the pump station. A limited number of potential readings were taken with the aid of measuring leads brought out at tapping and inspection points. Only one current reading was available, at the drainage point. First the basic pipe-to-soil potential was measured to a copper sulfate half-cell. The pipe was slightly anodic at the river end (Figure 7a). The drainage current was switched on for 74 hours. By taking the readings then and intermittently switching the current off, the resulting total drainage potential ϕ_i as well as the polarization potential ϕ_p were obtained. The total radial leakage voltage $U_r = \phi_i - \phi_b$, the polarization voltage $U_p = \phi_p - \phi_b$ and the ohmic leakage voltage $U_L = \phi_i - \phi_p$, were determined by graphical computation. The various methods of approach for evaluating such field data are shown in the following.

General Interpretation

The share of the polarization voltage U_p in the total leakage voltage is evident from Figure 7b. Up to a total voltage of U_r = 550 mV the polarization voltage by far exceeds the ohmic component. The polarization voltage U_p varies between 200 and 300 mV all along the line, while the ohmic voltage U_L starts from 65 mV and only near the drainage point crosses the 300 mV mark. Such early development of high polarization potentials is characteristic for cement coated lines.

A further remarkable feature of the voltage profile is the variation of the leakage voltage with changing soil resistivity conditions. The polarization voltage U_p has clearly visible peaks in the zones where the pipe reaches ground water, whereas the ohmic voltage U_L shows depressions in these sections, corresponding with a reduction of the leakage current. Considering the limited extent of these zones, the distortion of the ohmic voltage profile will be disregarded,

as indicated by the dotted lines in Figure 7b. The broken train of lines thus obtained for the U_L voltage, gives the approximate attenuation profile of the line.

For evaluation of the line constants the ohmic voltage values are as usual, plotted in a semi-logarithmic graph (Figure 8). The actually measured U_L profile, shown solid in the graph, appears at first sight unsuitable for correlation, due to the depression at points 26, 76 and 118. These depressions are eliminated, as previously mentioned, by drawing in the dotted line sections. The profile between points 100 and 115 is thereby extrapolated to point 88, corresponding with the high soil resistivity of the line embankment over the ground surface.

For a rough estimate consider the entire span between the drainage point, 16, and point 140 as an isolated uniform section (Figure 9a), free from interference voltages or local leakage currents. The approximate axial line resistance is assumed at

$$R_s = 63.3 \times 10^{-6} \text{ ohm/m},$$

comprising an empirical resistance factor $F = 2.5$. The ohmic voltage ratio for points 16 and 140 is 385/65. Referring to equation (26) for a limited span, in Appendix 2, the attenuation constant is

$$\alpha = \frac{1}{1240} \cdot \text{arc cosh } 5.92 = 1.98 \times 10^{-3} \frac{1}{\text{m}}.$$

The respective current (25) is

$$I_1 = \frac{65 \times 1.98 \times 10^{-3}}{63.3 \times 10^{-6}} \times \sinh (1.98 \times 1.240) = 11.80 \text{ amp.}$$

The potential profile corresponding with the above constants has been drawn out chain dotted. It should be noted that for a limited span the profile is not a straight line. The curve significantly deviates from the test points due to the varying soil conditions.

Profile Evaluation

For a higher degree of approximation the measured profile must be evaluated step by step. Starting from section 115-140, with a voltage ratio 73/65, the following values are obtained through a calculation similar to that for points 16-140:

$$\alpha = 1.96 \times 10^{-3} \frac{1}{\text{m}}; \quad I_1 = 1.02 \text{ amp.}$$

The unit conductance is in accordance with (8), $G = 18\,750 \times 10^{-6}$ mho/m².

The next span, between points 88 and 115, comprises the line section laid over the ground surface. It consists of a limited span with an axial current of $I_2 = 1.02$ amp. at its end point (Figure 9b). First the solution is approximated by applying a linear superposition. The axial voltage drop produced by I_2 at point 88 is

$$U'_{L1} = I_2 \cdot R_s \cdot w = 17.4 \text{ mV}. \qquad (12)$$

If this voltage is deducted from the ohmic voltage at 88, the balance obtained is

$$U''_{L1} = 93.0 - 17.4 = 75.6 \text{ mV}.$$

For this balance voltage the section shall be considered as an isolated span. The approximate attenuation constant obtained from equation (26) is $\alpha = 0.96 \times 10^{-3}$ 1/m. By substituting it into the exact expression (see Appendix 2)

$$\alpha w = \frac{w I_2 R_s \sinh \alpha w}{U_{L1} - U_{L2} \cosh \alpha w}, \qquad (13)$$

it is found that the error is negligible. The current of the superimposed circuit (25), is $I''_1 = 0.288$ amp. Therewith follows the resulting current at point 88

$$I_1 = 1.02 + 0.29 = 1.31 \text{ amp.}$$

The unit conductance (8) is $G = 4490 \times 10^{-6}$ mho/m², in agreement with the low moisture contents of the embankment covering the pipe.

By a similar approach there follows for points 39-88 an approximate constant $\alpha' = 1.90 \times 10^{-3}$ 1/m. Substitution into the exact equation (13) renders an error of 12.9 percent. By successive approximation of (13) the correct result is obtained, $\alpha = 1.80 \times 10^{-3}$ 1/m. The resultant current at 88 is $I_1 = 3.96$ amp. The conductance is $G = 15\,800 \times 10^{-6}$ mho/m².

Attempts to reproduce the attenuation curves in sections 16-39 and 16-3.2 indicate that, in addition to the low leakage resistance in this area an interfering ground bed potential must be considered at about point 16. Short of adequate soil potential measurements, the two sections will be evaluated summarily. A straight line voltage profile is assumed over these short spans and the pickup current is expressed as a function of mean unit conductance G,

$$I = 0.5(U_{L1} + U_{L2}) \times w \, D\pi \times G \text{ (mamp)}. \qquad (14)$$

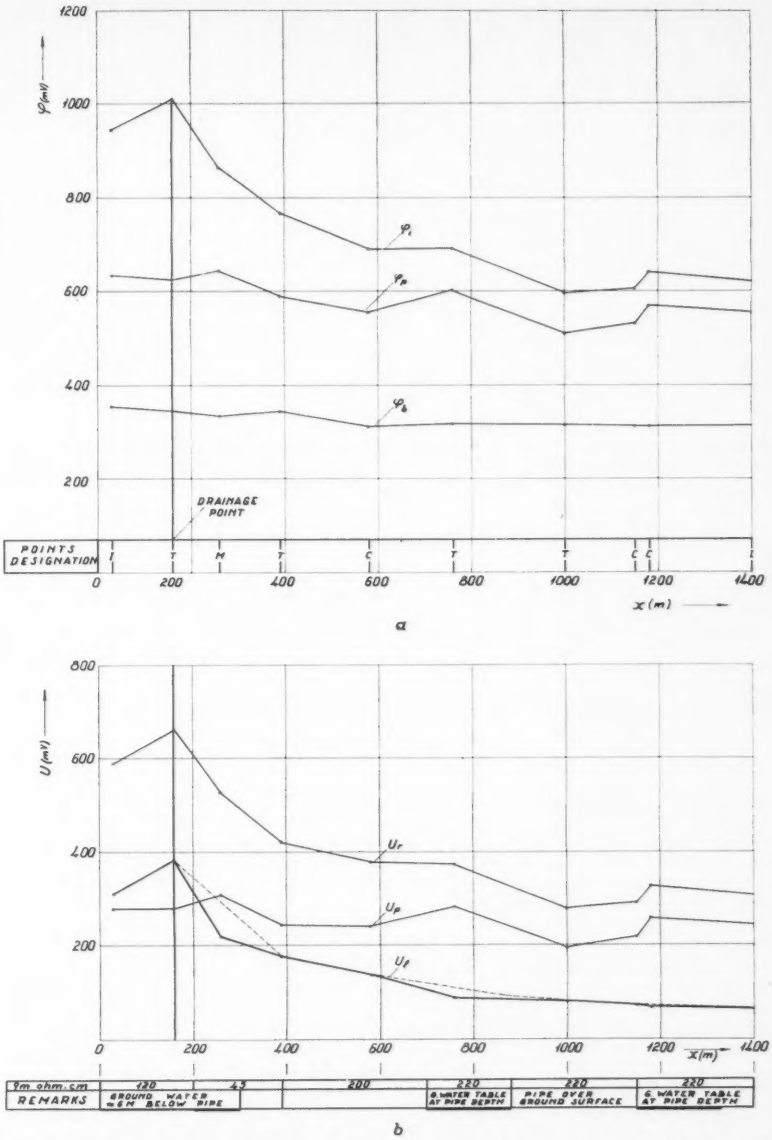

Figure 7—Line SA-31—Potential profiles for drainage current of 17.70 amp. (a) Pipe to soil potential; (b) Component voltage profiles. Code to letters is as follows: I, insulating joint; C, consumer's tapping; T, tapping flange; M, special measuring point.

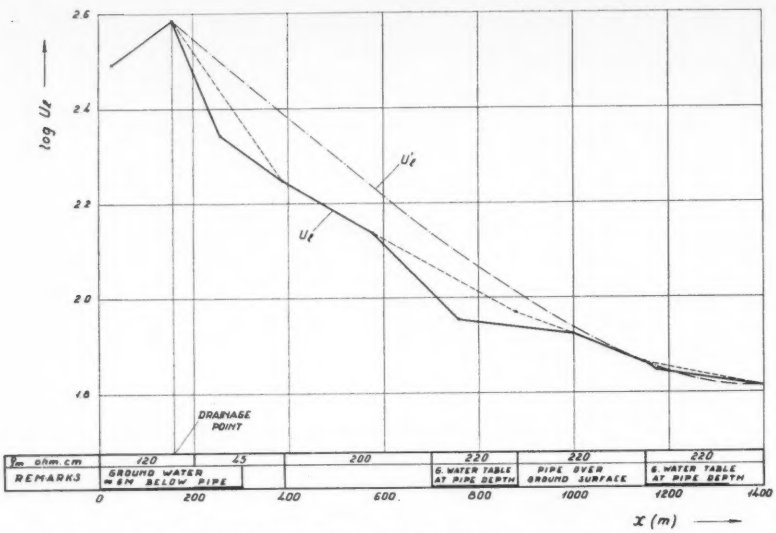

Figure 8—Line SA-31—Analysis of IR-voltage profile for drainage test shown in Figure 7.

Therein I denotes the balance of the current to be taken on

$$I = 17.70 - 3.96 = 13.74 \text{ amp.}$$

With the voltage U_L equal to 312.5, 385 and 177.5 mV at points 3.2, 16 and 39 respectively, there follows upon solution of equation (14) for the two sections

$$G \div 38\,900 \times 10^{-6} \text{ mho/m}^2.$$

This very high conductance has probably been caused by the extremely low soil resistivities and incipient corrosion attack in this area. The approximation has been verified by an estimate of the interfering ground bed potentials.

Summary

Table 3 gives the line data obtained for the various spans. From the average voltage values it follows that in the vicinity of the drainage point the numerical increase of the pipe to soil potential amounts to about 600 mV. Forty-five percent of this potential difference was caused by polarization. At the end of the line the potential difference was only 300 mV and as much as 77 percent of it was due to polarization effects.

The unit leakage resistances obtained from equation (6), reflect the moisture and salt contents of the soil. The current density J was computed by dividing the total pickup current of each section by the respective surface area of the pipe. It varies between 0.33 and 11.8 mamp/m². The gross current density of this drainage circuit is J = 4 mamp/m². In comparing the above values with bare or bituminous coated steel lines, the soil resistivity, the pipe diameter and the protective voltage should be taken into consideration.

Drainage Circuits Design

Current Loading

The economy of the design depends on the current loading ratio (i.e., the ratio of the gross current density J, derived from the total current input in relation to the minimum density j_z.)

It has been shown in Appendix 2 that for a limited span with insulated ends (Figure 9a), the loading ratio can be expressed as a function of the attenuation constant α and the length w

$$\frac{J}{j_z} = \frac{\sinh \alpha w}{\alpha w}. \qquad (15)$$

This simple expression is also valid for a line section of the length 2w, between two drainage points of equal intensity. From equation (15) it follows that for a constant loading ratio the span is inversely proportional to the attenuation constant α.

In Figure 10 the loading ratio has been plotted as a function of the product αw. It assumes the value of 1.0 at $\alpha w = 0$ and steeply rises to infinity with increasing abscissae. By expanding the expression (15) into a series an approximate value is obtained

$$\frac{J}{j_z} \div 1 + \frac{(\alpha w)^2}{6}, \qquad (16)$$

which is sufficient for preliminary calculations.

Example 1

The spacing between evenly distributed drainage points has to be found, for a 48 inch prestressed concrete line, with an attenuation constant $\alpha = 2.0 \times 10^{-3}$ 1/m.

1a. What is the spacing 2w with an ohmic voltage ratio $U_{L1}/U_{Lmin.} = 2.5$?
Answer:

$$w = \frac{1}{2.0 \times 10^{-3}} \text{arc cosh } 2.5, \quad \text{(See eq. 26)}$$

$$2w = 2 \times 782 = 1564 \text{ m.}$$

1b. What will be the current loading ratio?
Answer:

$$\alpha w = 2.0 \times 10^{-3} \times 782 = 1.56,$$

$$\frac{J}{j_z} = \frac{\sinh 1.56}{1.56} = 1.46. \quad \text{(See eq. 15)}$$

The approximation formula (16) gives

$$\frac{J}{j_z} \div 1 + \frac{1.56^2}{6} = 1.407,$$

i.e., the error is 4 percent.

TABLE 3—Line SA-31—Performance Data After a Drainage Test of 74 Hours at I = 17.70 amp.*

Station —	Span m	MEAN VOLTAGE U_r mV	MEAN VOLTAGE U_p mV	MEAN VOLTAGE U_L mV	LINE CONSTANTS α 10^{-3} x 1/m	LINE CONSTANTS R_L ohm.m	LINE CONSTANTS G 10^{-6} x mho/m²	CURRENTS J mamp/m²	CURRENTS ΔI amp.	CURRENTS I amp.
3.2										
	128	628.7	280.0	348.7						
16					2.82	7.94	38 900	11.8	13.74	17.70
	230	543.7	262.5	281.2						
39										3.96
	490	374.2	239.0	135.2	1.80	19.6	15 800	1.67	2.65	
88										1.31
	270	399.2	226.2	83.0	0.96	68.9	4 490	0.33	0.29	
115										1.02
	250	300.0	231.0	69.0	1.96	16.5	18 750	1.26	1.02	
140										

* Axial Line Resistance: $R_a = 63.3 \times 10^{-6}$ ohm/m.

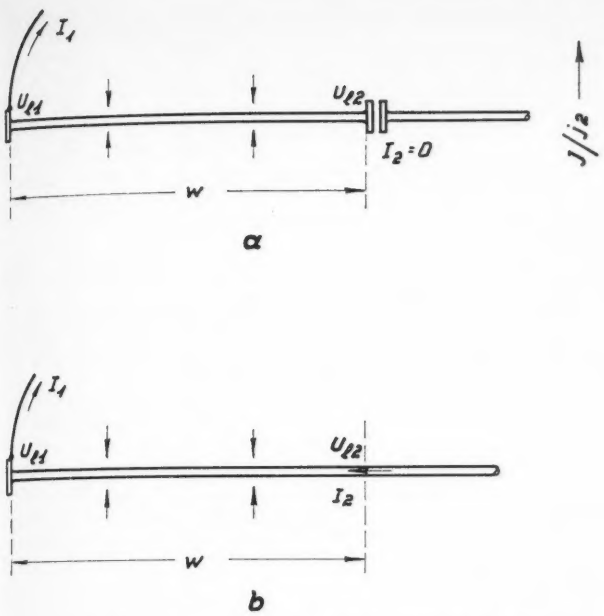

Figure 9—Limited line section. (a) With both ends insulated; (b) With an axial current I_2 at the far end.

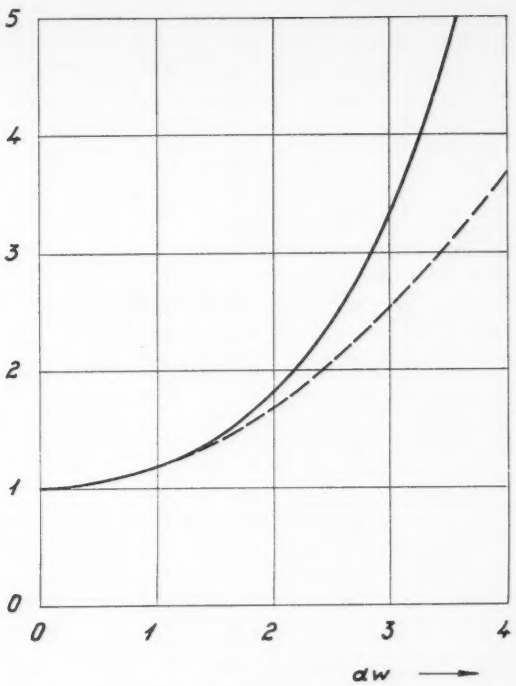

Figure 10—Current loading ratio for limited span insulated at its ends. Solid line shows exact curve; dotted line shows approximate curve.

Example 2

On another section of the 48 inch line the attenuation constant is $\alpha = 1.4 \times 10^{-3}$ 1/m.

2a. What is the largest span w permissible for a loading ratio of $J/j_2 = 1.2$? Answer: The approximate value is according to (16).

$$\alpha w \div \sqrt{[6(J/j_2 - 1)]}$$

$$\alpha w \div \sqrt{[6(1.2 - 1)]}$$

$$w \div \frac{\sqrt{1.2}}{1.4 \times 10^{-3}} = 784 \text{ m.}$$

This value substituted in the exact equation (15), gives $J/j_2 = 1.21$; viz. only 1 percent more than the assumed value.

2b. What is the ohmic voltage ratio for $2w = 1500$ m between drainage points of equal intensity? Answer:

$$\frac{U_{L1}}{U_{L\,min.}} = \cosh\,(1.4 \times 10^{-3} \times 750) = 1.60. \text{ (See eq. 26)}$$

2c. What will the voltage ratio be in the rainy season, when the leakage resistance R_L will be reduced to 70 percent of its present value? Answer:

$$\alpha' w = (1/\sqrt{0.70} \times 1.4 \times 10^{-3}) \times 750 = 1.25, \quad \text{(See eq. 7)}$$

$$\frac{U_{L1}}{U_{L\,min.}} = \cosh 1.25 = 1.88.$$

Feeding Points

At the high attenuation constants of prestressed concrete lines the feeding span must be reduced to comply with given current loading ratios. At an attenuation constant $\alpha = 2.5 \times 10^{-3}$ 1/m for example, the spacing between feeding points should not exceed $2w = 1200$ m. These short feeding spans increase the cost of cathodic protection. A high tension feeder line or a series of wind generators may become necessary to provide for the drainage energy on a long line. The use of magnesium anodes is under these circumstances restricted to special cases.

Nevertheless, electrical drainage is of importance in corrosive environments. In sulfate-rich soils it prevents dangerous ion migration liable to destruct the mortar coating. Steel wires susceptible to stress corrosion can be protected. On operating lines cathodic protection offers practical means for meeting unforeseen corrosion difficulties. Lines which have been bonded and provided with insulating joints during construction, are at any time ready for taking the drainage current. The opening up and bonding of old concrete lines is however an expensive proposition. Spot protection may then be the only way to avert corrosive attack.

Constructional Details

The following structural precautions are essential for the protection of prestressed concrete pipe.

Bare Steel Components. Steel fittings, flanges, adaptors and line tappings which have not been separated by insulating joints, must be cement coated, unless a special cast bituminous coating is provided.

Continuity Bonds. Electrical bonding of pipe joints is required on pipe with non-embedded steel cylinder, as previously explained.

Insulating Joints. Insulating joints shall be placed in well drained pits. Valve or inspection pits may be suitable for this purpose.

When located underground, an adequate coating is required. On flange-gaskets a half inch projection at the outer edge is of great advantage. Rubber components on couplings and flanges should be protected by synthetic tape from direct contact with bituminous compounds. Inert backfill over a length of 3 feet on each side of the joint is desirable.

Measuring Points. Measuring leads are to be carried out from all insulating joints, line terminations, tappings, expected interference spots and at any other critical point.

The cables are to be reliably insulated and laid deep enough to avoid mechanical damage. The leads shall be terminated in junction boxes or special pipe sockets. Boxes are to be mounted on concrete or steel posts, high enough to remain visible. Rustproof, secret key locking bolts are to be used for the box covers. Steel posts are to be grouted into precast concrete blocks, projecting 8 inches above ground level. All steel parts are to be suitably painted.

Sacrificial Anodes. In addition to known rules, care must be taken to secure a minimum of soil moisture in arid areas. This is achieved by placing the

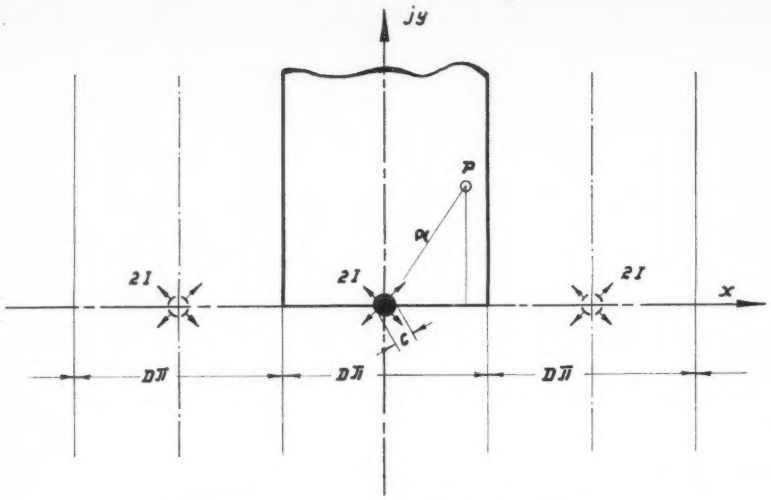

Figure 11—Two-dimensional field for calculation of fringing effect.

anode at great depth or by artificial watering. Sulfate backfill, such as gypsum, to be used only at distances of more than 9 feet from the pipe surface. Adequate measuring facilities are important in the case of concrete lines.

Ground Beds. The distance from the line axis and the layout to be so chosen, as to reduce the effects of local ground potentials. Electrode assemblies shall not be laid-out parallel to the line axis.

For similar reasons the ground bed shall not be placed near a brook, underground pipes or cables crossing the line. This condition is of particular importance in arid areas.

Construction Schedule. All provisions, starting from continuity bonds, shall be completed and tested in the course of construction. The omission of a single measuring point may in the long run cost more than the accessories of an entire line section.

Inspection and Maintenance. The protective measures can be relied upon only as long as they are periodically inspected and maintained.

Conclusions

1. Prestressed concrete lines of the non-embedded cylinder type are to be provided with continuity bonds.

2. Pipe with the axial reinforcement embedded in the concrete core is preferably left unbonded.

3. Cathodic protection is applicable to the bonded lines only.

4. The axial resistance of the lines is high due to the reduced amount of steel and to fringing effects.

5. The leakage resistance significantly varies with soil conditions.

6. High polarization voltages support the protective action.

7. Owing to high attenuation constants shorter drainage spans are required than in bituminous coated systems.

8. Electrical drainage is of particular value on existing lines, for meeting unforeseen corrosive conditions.

Acknowledgment

Acknowledgment is made to E. Balaban, Head, Design Office, Water Planning for Israel, Ltd., for permission to publish this paper. Appreciation is extended also to S. Ofer and the staff of the Cathodic Protection Group for the field measurements and to Messrs. Mekoroth Water Company for the data supplied.

Appendix 1—The Fringing Resistance

The spreading resistance of the axial current entering the pipe cylinder through a continuity bond can be analytically reproduced. If no other contact point exists at the joint and the steel cylinder is of a constant mean thickness t_s, the current field is represented by a two dimensional distribution as shown in Figure 3.

Consider the development of the pipe cylinder and replace the bonding weld by a cylindrical surface of the small diameter, c, normal to the pipe surface (Figure 11). The current discharge into the steel sheet over the whole periphery of this bonding cylinder shall be 2I. It creates a symmetrically rotational field about the axis of the bonding cylinder. This axis can be considered as a source line of the current loading

$$i = \frac{2I}{t_s} \text{ amp/cm}, \qquad (17)$$

where t_s denotes the thickness of the pipe cylinder sheet. The trace of this source line on the drawing plane shall be assumed as the origin of a complex coordinate system (x; jy).

In an infinite medium the current would spread radially from the source line, with cylindrical equipotential surfaces, intersecting the drawing plane in concentric circles about the origin of the coordinate system. In order to produce a current distribution complying with the boundary conditions of the present case, an infinite series of equidistant equally charged source lines must be assumed in accordance with the known method of reflected images. For a source line spacing equal to the circumference of the pipe cylinder $D\pi$ the potential produced at a point P by the bonding current spreading into the pipe cylinder, is given by[3]

$$\phi = -\frac{i}{2\pi} \cdot \rho_s \cdot \text{Re ln sin } \frac{q}{D}. \qquad (18)$$

Therein ρ_s denotes the steel resistivity, q is the complex vector $(x + jy)$, and Re designates the real component of the complex expression.

On the y-axis, for $x = 0$, (18) assumes after some transformation the form

$$\phi = -\frac{i}{2\pi} \cdot \rho_s \cdot \text{Re ln j sinh } \frac{y}{D}. \qquad (18a)$$

Hence follows the potential difference $(\phi_o - \phi_1)$ for two points at the distances y_o and y_1, after reduction by j,

$$U = +\frac{i}{2\pi} \cdot \rho_s \cdot \ln \frac{\sinh \frac{y_1}{D}}{\sinh \frac{y_o}{D}}. \qquad (19)$$

For small values $y_o \ll D$ the denominator of the fraction can be replaced by y_o/D. Whereas for very large distances $y_1 \gg D$

$$\sinh \frac{y_1}{D} \div \tfrac{1}{2} e^{y_1/D}. \qquad (20)$$

As a result (19) can be replaced by

$$U \div + \frac{i\rho_s}{2\pi D}\left(y_1 + D \ln \frac{D}{2\, y_o} \right). \qquad (21)$$

Considering with reference to (17), that the expression $it_s/2$ gives the current I entering the steel cylinder of the pipe, and $2y_o$ is identical with the width of the bonding weld c, the axial resistance of the pipe cylinder up to a large distance y_1 is

$$R = \frac{\rho_s}{\pi\, Dt_s}\left(y_1 + D \ln \frac{D}{c} \right). \qquad (22)$$

In other words, the fringing effect produces an increase of the net cylinder resistance originally obtained for parallel current flow, equivalent to an extension of axial length

$$\Delta L = D \ln \frac{D}{c} \qquad (1a)$$

at each end of the pipe.

If the axial current enters the pipe at more than one point, the respective potential fields must be superimposed. A contact between the joint rings, for example, located diametrically opposite the continuity bond, of equal resistance and width c′, produces in the cylinder a current distribution similar to that of the bond. As a result the value D/2 has to be substituted for D in the fraction under the logarithm of expression (1a), to obtain the equivalent increase of axial length.

Appendix 2—Attenuation Functions For Limited Span

The IR voltage profile shall be investigated on a uniformly coated line of the axial resistance R_s and the constant leakage resistance R_L. A section of the variable length w is assumed, with an impressed current I_1 and the voltage U_{L1} at the feeding point, the respective values at the far end being I_2 and U_{L2}.

Isolated Line Section

If the line is insulated at the far end, $I_2 = 0$, as indicated in Figure 9a, the voltage U_{L1} is given by the known expression.[4]

$$U_{L1} = U_{L2} \cosh \alpha w. \quad (23)$$

The impressed current is

$$I_1 = \frac{U_{L2}}{R_k} \sinh \alpha w. \quad (24)$$

As from equations (7) and (9) it follows that the attenuation constant α is equal to R_s/R_k, the current I_1, can be expressed by

$$I_1 = \frac{U_{L2} \cdot \alpha}{R_s} \sinh \alpha w. \quad (25)$$

When the ratio of the ohmic voltages U_{L1}/U_{L2} is known, the attenuation constant is obtained from (23)

$$\alpha = \frac{1}{w} \text{ arc cosh } U_{L1}/U_{L2}. \quad (26)$$

Expressions (23) to (26) apply equally well to a section of the length 2w between two drainage points of equal intensity.

Line Section with the Axial Current I_2 at Its End

For a line section with the voltages U_{L2} and the axial current I_2 at the distance w (Figure 9b) the voltage U_{L1} will be derived by superposition. It is considered to be composed of a component U'_{L1} related to an infinite line, carrying the axial current I_2 at the distance w and a component U''_{L1} produced by the balance of the system,

$$U_{L1} = U'_{L1} + U''_{L1}. \quad (27)$$

Referring to the basic equation of an infinite line, then

$$U'_{L1} = U'_{L2}\, e^{\alpha w}, \quad (28)$$

and upon substituting the product I_2R_k for U'_{L2}

$$U'_{L1} = I_2R_k\, e^{\alpha w}. \quad (29)$$

Similarly there follows with reference to (23)

$$U''_{L1} = (U_{L2} - I_2R_k) \cosh \alpha w. \quad (30)$$

By substituting (29) and (30) in (27) and introducing for the hyperbolic function its exponential equivalent, after some transformation the equation is

$$U_{L1} = U_{L2} \cosh \alpha w + I_2R_k \sinh \alpha w. \quad (31)$$

For interpretation of line tests the characteristic resistance R_k is again replaced by R_s/α (25), so that equation (31) can be converted into

$$\alpha w = \frac{w I_2 R_s \sinh \alpha w}{U_{L1} - U_{L2} \cosh \alpha w}. \quad (13a)$$

Loading Ratio

The loading ratio of an isolated section shall be expressed by the attenuation constant α and the span w (Figure 9a).

The net current input for uniform density j_2 would be

$$i_1 = w \frac{U_{L2}}{R_L}, \quad (32)$$

wherein U_{L2}/R_L expresses the current $D\pi \cdot j_2$, taken on along one meter axial length. If this net current pickup is related to the actual current input I_1 (25), there follows after some reduction

$$\frac{I_1}{i_1} = \frac{\alpha R_L}{R_s w} \sinh \alpha w. \quad (33)$$

Upon substituting the average gross current density J for I_1 and the density j_2 for i_1, one obtains with reference to (7) the simple ratio

$$\frac{J}{j_2} = \frac{\sinh \alpha w}{\alpha w}. \quad (15a)$$

Appendix 3—Symbols Used

Reference equation numbers are given in brackets.

D = Diameter of steel cylinder.

F = Resistance factor (2).

G = Unit conductance, the reciprocal value of the ohmic leakage resistance, R_L, reduced to one square meter of the steel cylinder surface (5, 6).

I = Impressed axial current.

J = Impressed radial current density, mean value for whole span (15).

L = Length of steel cylinder.

R_c = Coating resistance per one meter length of line (3).

R_k = Characteristic resistance of an infinite line (given by the ratio of IR voltage drop at the drainage point to the impressed axial current drawn from one arm of the line). Expressions (9, 10) give the resistance R_k for one side of the line only.

R_L = Ohmic leakage resistance given by the ratio of the total IR voltage drop, U_L, to the leakage current for one meter axial length of the line (3).

R_m = Spreading resistance in the surrounding medium given by the ratio of the voltage drop U_m to the leakage current for one meter axial length of line (3).

R_s = Axial ohmic resistance of the equivalent steel cylinder, per running meter.

Re = Real part of complex mathematical expression (18).

U_c = IR voltage drop across the pipe coating caused by impressed currents.

U_L = Total IR voltage drop caused by impressed current (measurable with respect to an agreed reference point in the ground (3).)

U_m = Voltage drop in the surrounding medium caused by the spread of impressed current (measurable between two half-cells (3).)

U_p = Polarization voltage caused by impressed currents (defined as the nonlinear component of the resulting voltage drop U_r.)

U_r = Resulting transversal voltage drop caused by impressed current (measurable with respect to an agreed reference point in the ground). Comprises the ohmic voltage, U_L, and the polarization voltage, U_p.

c = Peripheral width of the bond (1).

i = Current loading of source line (17).

i_1 = Net current input (32).

j = Impressed radial current density, net value (15, 32).

q = Vector in the complex plane [x + jy] (18).

t_c = Thickness of coating.

t_s = Thickness of equivalent steel cylinder.

w = Length of line section.

α = Attenuation constant in the exponential expression for the ohmic voltage U_L as a function of distance (7, 8, 11).

ρ_c = Resistivity of coating.

ρ_s = Resistivity of steel reinforcement.

ϕ = Potential of the pipe reinforcement with respect to a half-cell at an agreed reference point in the ground.

ϕ_b = Basic potential when no impressed current is flowing; may comprise voltage drops caused by natural galvanic currents and stray currents.

ϕ_i = The resulting potential, when an impressed current is superimposed over the natural ground currents.

ϕ_p = The potential measured immediately upon shutting down the impressed current; comprises the polarization voltage U_p.

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Any discussion of this article not published above will appear in the December, 1960 issue.

Microbiology in Secondary Recovery Systems*

By L. L. WOLFSON

Abstract

A general discussion is given of the role of microorganisms in secondary recovery systems, including the interrelationship of the organisms with chemical scale and corrosion. Specific types of microorganisms discussed include iron bacteria, algae and fungi, slime formers, and corrosive (sulfate reducing) bacteria.

The life cycles and nutritional requirements of the organisms are discussed, with emphasis on the effects of the different types of bacteria on each other. A genus of organisms, capable of hydrogen sulfide production, and previously not implicated in secondary recovery problems, is presented and described. 3.3.4

Introduction

"SECONDARY RECOVERY," and "waterflood systems" are terms used interchangeably in the petroleum industry. They refer to systems in which water is introduced into an oil formation through an injection well, thereby forcing oil to the surface at the producing well. This method allows the removal of oil from the formation after primary recovery has ceased.

Classification of Microorganisms

The microorganisms of interest in secondary recovery operations are as follows:

1. Iron bacteria
2. Algae and fungi
3. Slime formers
4. Other types
5. Corrosive bacteria

Iron Bacteria

The iron bacteria are those organisms that deposit a sheath of iron hydroxide around themselves as they grow. The iron is obtained from the soluble iron in the system. This group includes organisms such as *Gallionella, Sphaerotilus, Crenothrix,* etc. These bacteria can be found in shallow or deep wells, rivers, lakes, or any place where fresh water, stagnant water or sewage water is available.

Some of these bacteria will deposit manganese when it is available instead of iron. Such organisms have been thought for many years to be obligate aerobes (i.e., organisms that grow only in the presence of free oxygen.) However, several papers recently have shown that some of these organisms can grow well with only trace amounts of oxygen. This implies that iron depositing bacteria may be found where they had been thought before to be incapable of growth. The iron bacteria, when they build up in a system, can cause cloggging of the pipes, filters, screens, etc. They slough off into the system in chunks causing large particles of ferric hydroxide to be distributed throughout the system. When they form heavy layers, they provide anaerobic conditions for corrosive bacteria to multiply underneath.

Algae and Fungi

There has been little trouble experienced with fungi in waterflood systems. The systems generally are not conducive to the growth of such organisms.

The algae are plants that require sunlight for growth. For this reason, the primary trouble with algae in waterflooding is in the open type systems where growth will occur in reservoir pits, river waters, and in open tanks. There are, of course, many types of marine algae, but up to the present time, there is no evidence to indicate that they have caused trouble in systems using sea brine for waterflooding purposes.

Fresh water algae grow on the surface of the water in a pond or tank, where they serve as food source for bacteria. They often form a blanket over a pond or tank, making conditions ideal for the growth of sulfate reducing bacteria in deeper regions of the water. The algae growths often slough off and then cause problems by plugging filters, pipes, etc.

Slime Formers

The slime formers include bacteria that proliferate on surfaces such as the sides of tanks, filters, inside pipes, etc. These organisms utilize oxygen in their metabolism and when they proliferate they produce dense slime masses, which will completely prevent oxygen from penetrating the slime mass. The slime therefore, serves as an excellent covering so that sulfate reducing bacteria can multiply extremely well underneath the slime. In addition, slime in itself can very effectively clog a filter or completely close a pipe. The author had occasion to treat a waterflood system where no treatment had previously been used. There was no trouble in this system when it started and it ran about twelve months before plugging of the overland water pipes occurred. Before treatment, a six inch pipe, after being manually cleaned, would close up completely, because of slime, in a five day period. The slime forming bacteria can cause trouble in lines of supply wells and injection wells and slime can also be an important factor in increasing injection pressure and reducing the volume of water being injected because of the blocking of the sand face. It is absolutely essential, in a waterflood system, to keep slime under control at all times.

Slime in a system sloughs off from time to time, and the organisms thus get a chance to move to another area and contaminate other parts of the system. A peculiarity in the growth characteristics of these organisms is often overlooked and must be watched. It is usual to suspect, in a flowing system such as a water line, that the slime, once it begins to proliferate in an area, will grow in the direction of the water flow and that direction only. This is not true. Slime in a system will move in all directions, and a supply well in good condition bacteriologically can become heavily contaminated with slime because of the reverse growth of the organisms to the source well. This means, of course, that a source well will very often require occasional treatment to keep it in good microbiological condition. The organisms capable of causing slime in water flood systems belong to the genera *Pseudomonas, Flavobacterium, Escherichia, Aerobacter,* and *Bacillus.* Many of these organisms are halophilic, that is, they grow well in the presence of sodium chloride concentrations as high as ten percent. Thus, slime can be expected in fresh water or brine systems.

Other Types of Bacteria

The other types of bacteria include all those not mentioned above exclusive of corrosive bacteria. To date, there has been little work done on these other types of organisms found in water flood systems. Generally speaking, if these other types are kept below a level of 100,000 organisms per milliliter, no trouble is experienced with them. However, if a series of analyses shows increasing

About the Author

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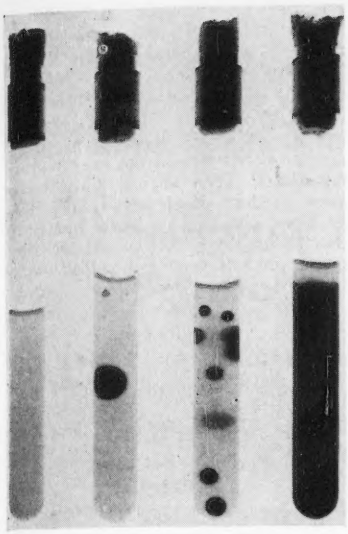

Figure 1—Tenfold dilutions of sulfate reducing bacteria *(Desulfovibrio)* in API medium.

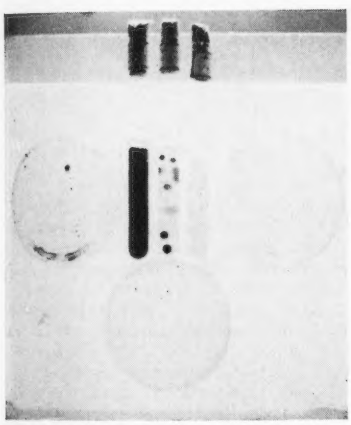

Figure 2—Tenfold dilutions of sulfate reducing bacteria *(Desulfovibrio)* in API medium in Petri dishes and test tubes.

numbers of these bacteria, so that the counts begin to run into the millions, that is good evidence that the system requires control measures. These bacteria can cause trouble by blocking a filter or a sand face just by sheer numbers when the counts get high. They are also a good indicator, in that, if they are multiplying in the system, chances are good that troublesome organisms such as the slime formers and corrosive bacteria will also find conditions ideal for propagation.

Corrosive Bacteria

Last, and by far the most important bacteria in secondary recovery, are the corrosive bacteria, commonly known as the sulfate reducing bacteria or the *Desulfovibrio*. The literature has been copious in the last five years on the incidence of sulfate reducers and their effect in waterflood systems. This is not without good cause, because a three-year study by the API subcommittte on Biology in Secondary Recovery Systems has shown that the occurrence of these organisms is widespread. They produce hydrogen sulfide, which leads to the production of the insoluble black compound iron sulfide, which in turn produces a pitting type of corrosion in iron pipes.

The sulfate reducers are obligate anaerobic, autotrophic bacteria. Obligate anaerobes are organisms that will not grow in the presence of atmospheric oxygen. This is in contrast to obligate aerobic organisms that must have free oxygen for growth to take place. Facultative aerobes, on the other hand, are bacteria that can grow either with or without the presence of atmospheric oxygen.

All living organisms absolutely require two chemicals which are building blocks of protein, for propagation. These two elements are carbon and nitrogen. Bacteria are further classified by the source of their carbon. If the carbon is obtained from organic matter, such as carbohydrates, amino acids, proteins, etc., they are called heterotrophic bacteria. If the carbon is obtained from an inorganic source such as carbon dioxide or carbonate salts, they are called autotrophic bacteria. Here, sulfate reducing bacteria manifest a split personality, because although they are autotrophs they will utilize organic carbon.

The sulfate reducers are motile, nonspore forming, comma or spiral shaped bacteria. They are found in lakes, rivers, ocean waters, wells, marshes, soil. In fact they may be present in any water where anaerobic conditions are available. These bacteria have also been isolated from air in which water droplets have been suspended. The optimum growth occurs at a pH of 7, but they will grow in the pH range of 5.5 to 8.5. They appear to cease reproduction at pH of five or lower, or nine or higher. These organisms grow in a redox potential of plus 100 to minus 500 millivolts. They grow best in temperature ranges between 75 and 110 F, but they have been found proliferating at temperatures of 32 F and 212 F. They grow at the latter temperature only in regions where there is a high hydrostatic pressure, such as deep in an oil formation, or in simulated laboratory conditions.

Sulfate reducers have been found multiplying in fresh water and in brines containing from 1 percent to 30 percent sodium chloride. They can tolerate brines of any salinity provided that the sodium chloride content is the same as in their natural environment. Cultures have been made to grow in other than their natural brines. This requires step-wise adaptation.

Figures 1 and 2 show colonies of sulfate reducing bacteria growing in API medium both in agar tubes and agar plates. They are arranged in tenfold dilutions so that counts of the number of organisms per milliliter can be made. The sulfate reducers appear as black colonies, due to the production of hydrogen sulfide by the bacteria and the soluble iron in the system, causing the precipitation of iron sulfide around the colonies.

The sulfate reducers obtain their energy by reduction of the sulfate ion. This necessitates the use of hydrogen for the reaction, this element being supplied by an organic compound such as lactate or by molecular hydrogen. These organisms are unique in being able to utilize molecular hydrogen for production of hydrogen sulfide. They can also produce hydrogen sulfide by the reduction of thiosulfate, tetrathionate, and sulfite.

Sulfate reducers are not the only organisms that produce hydrogen sulfide. Other bacteria that can do this include *Pseudomonas, Proteus, Flavobacterium* and *Aerobacter*. These sulfide producers are facultative anaerobic, heterotrophs and obtain their sulfur from the breakdown of protein or amino acids containing sulfur. Insofar as is known, these bacteria have never been significant hydrogen sulfide producers in secondary recovery systems.

Waterflooding Problem

About one and a half years ago, a new problem was encountered in the waterflooding microbiology field. In the regular laboratory media, used for isolating and counting sulfate reducers, no bacteria were found to be present in a particular system. Yet the men in the field reported that the actual flood water would turn black upon standing. Investigation of the water revealed the presence of organisms that to the author's knowledge, have never been implicated in secondary recovery systems as significant hydrogen sulfide producers.

These bacteria belong to the genus *Clostridium*. The *Clostridia* are obligate anaerobic, spore forming bacteria, heterotrophic in their metabolism. These bacteria produce gas and emit a putrefactive odor when they proliferate. They are found in fresh water, brines, sewage, and soil. They obtain their sulfur for the formation of hydrogen sulfide from proteins and amino acids, although one species can reduce inorganic sulfate just as the sulfate reducers, provided that organic matter is present for their metabolic activities. Bacterial spores, such as formed in *Clostridia*, are a resting stage in the life of the organism whereby they are able to withstand adverse conditions, such as extremes in temperature, pressure, chemicals, lack of food, etc. When the bacterium is in the spore stage, normal metabolic activities do not take place, such as production of hydrogen sulfide. However, the spores are extremely resistant to attack so that they are difficult to kill in a system. When conditions improve, the spore germinates and begins again its normal activities. Thus organisms are in existence that are going to present a different type of problem from that encountered heretofore.

Media were soon developed for isolating and counting this organism when present in a system. Steps were then taken to determine whether these bacteria were present in other waterflood systems. Investigations showed them to be present in secondary recovery systems in Texas, Oklahoma, Illinois, Indiana, Kansas and California.

Work is now under way to develop better methods of isolation and enumeration of the bacteria, species identification,

corrosive contribution in water flooding, and development of even better chemicals for their control. Further work on the *Clostridia* is now in progress.

Corrosion Damage From Bacteria

Sulfate reducing bacteria in pipe lines and equipment can cause corrosion damage in several ways. First, of course, corrosion can be caused by hydrogen sulfide itself, which can be accelerated by the presence of small amounts of oxygen. Next to consider is the corrosion as a result of electrochemical reactions propagated by the sulfate reducing bacteria. Under normal conditions, iron or steel lines submerged in water will develop anodic and cathodic areas, and if depolarization does not occur, an equilibrium is reached and no further corrosion results. In anaerobic conditions, where the sulfate reducers are present, these organisms act as cathodic depolarizers by utilizing the hydrogen formed, and as a result the electrochemical process is accelerated.

When this happens a pitting type of corrosion occurs. As the hydrogen sulfide forms and diffuses into the water, it produces reducing conditions which accelerate the growth and spread of the sulfate reducers. The corrosion then spreads over a larger area and a slab or generalized type of corrosion occurs. Iron sulfide, which is formed as a result of the action of the dissolved hydrogen sulfide and iron, is cathodic to metallic iron and its presence can therefore help to accelerate corrosion. The sulfate reducers, unfortunately, do not confine their activities to iron. They will attack and penetrate cables, cement, and cement-based materials. They are becoming increasingly troublesome in wells because of casing corrosion.

Chemical corrosion enhances growth of the sulfate reducing bacteria. As mentioned previously, these organisms grow only in the absence of free oxygen. However, in an oxygenated system, when corrosion products such as iron oxide are deposited on the pipes, the corrosion products act as a protective layer in preventing the oxygen in the system from coming in contact with the bacteria. Therefore, these bacteria develop lustily in secluded areas, producing pits in the pipe. The same phenomenon occurs in the presence of scale formation, where the scale acts as the shield against the penetration of the oxygen. Furthermore, corrosion products and scale make it extremely difficult for bactericidal treatment to eliminate these organisms, because just as the oxygen can not get at the bacteria, neither can the chemical. Indiscriminate treatment of a secondary recovery system can, therefore, lead to a false sense of security.

The role of the *Clostridia* in a secondary recovery system is not yet completely understood. It is known, however, that they produce hydrogen sulfide. Thus, whatever problems can occur in a system due to hydrogen sulfide and the subsequent production of iron sulfide, can be caused by them. Presumptive laboratory evidence is available that *Clostridia* can produce a generalized or slab type of corrosion, and there is good field evidence that they will produce pitting. It remains then for the research program to supply the final proof of these observations.

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Any discussion of this article not published above will appear in the December, 1960 issue.

Technical Papers on Corrosion Welcomed

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Industrial Maintenance Painting Program

NACE TECHNICAL COMMITTEE REPORT

Publication 60—8

A Report of NACE Technical Unit Committee T-6D*
On Industrial Maintenance Painting, Prepared by
Task Group T-6D-3** on Paint Programs

Abstract

An outline is given of current industrial practices in establishing and sustaining industrial maintenance painting programs. Specific areas of the program covered in detail include administration, specification (materials, equipment and methods), application, inspection and evaluation. Attention is given here to such matters as organization for industrial maintenance painting, cost factors, supply of materials, training programs, safety, and evaluation of environment. Data received from questionnaire replies are tabulated. Organizational charts used in carrying out actual painting programs are reproduced. 1.7.1

Introduction

TASK GROUP T-6D-3 was organized to present a complete and comprehensive industrial maintenance painting program for use by industry. The program has evolved from experiences and practices of industry in the field of industrial maintenance painting. The program is designed so that it is readily adaptable to various sizes and types of industry by taking those portions applicable, based upon the needs of the plant and desires of management.

Foreword

Industrial maintenance painting is the application of a protective coating system to materials of construction, usually steel, for protection against atmospheric corrosion. This definition includes maintenance of existing protective coatings systems as well as application of entire new systems.

Atmospheric corrosion is defined as that environment consisting of the elements of nature, the air pollution of the general industrial area, plus the traces of chemicals within the plant itself. Chemical spillages present unusual problems and are not considered as a part of a corrosive atmosphere.

An industrial maintenance painting program is the administration, specification, application, inspection and evaluation of protective coating systems.

This report, based upon current industrial practices and experiences, presents an outline of an industrial maintenance painting program. The outline includes all phases of a program deemed necessary, though emphasis on each phase and manner of accomplishment of individual portions will vary with:

Size of industrial plant
Type of industrial plant
Corrosive atmosphere
Geographical location
Economy
Desires of management

Each of the basic phases discussed in this paper should be accounted for in the planning for the painting program.

Administration

The administrative phase includes the managerial and supervisory functions for the accomplishment of an industrial maintenance painting program (IMPP). These functions should include the following either as a combined responsibility under one or more divisions or, in a large organization, specific provisions should be made for each:

Purpose of IMPP

The general statement of the aims and purposes of the IMPP as originated by management.

Responsibility

The responsibility for the entire IMPP should be clearly stated. Practice in industry varies considerably in this matter. On one hand, a single individual heading one department has responsibility for all phases of the IMPP as herein outlined. On the other hand, in some companies each phase of IMPP is the responsibility of different departments which may be either local or in the "home-office". Departments involved usually include one or more of the following:

Maintenance
Engineering
Operations
Purchasing
Contract Section

Also, outside personnel may become involved in the responsibility, such as inspection agencies, contractors and consultants.(1)

In general, the recommended approach to responsibility is that all phases of the IMPP be delegated to one department which has at its disposal the advice, recommendations and guidance of other groups. The location of this department in the plant organization and selection of the head of this department is governed by plant size and policy, as well as by amount of industrial maintenance painting to perform.

Organization for IMPP

This is the arrangement of personnel for supervision and accomplishment of all activities under this IMPP.

Supervision. As in the placement of responsibility, the supervision of the entire IMPP can be given to one person as the head of a Protective Coatings Division, or then again supervision can be decentralized into each, or any combination of, the five major parts (i.e., Administration, Specification, Application, Inspection and Evaluation) of the IMPP. Many factors are to be considered in the selection of degree of supervision as well as the supervisors to be involved. As under heading "Responsibility," factors to be considered are such things as size of the industry, amount of IMPP, company policy and practices, etc. In addition, the selection of, and responsibility given to the supervisors must concern the qualifications of the individuals involved. If one person is to have responsibility for the entire IMPP, he should possess all the desirable characteristics of leadership, be well grounded technically as well as possessing a background of experience in the protective coatings field.

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** F. P. Helms, Union Carbide Chemicals Co., Texas City, Texas, Chairman.

(1) Questionnaire results compiled by Task Group T-6D-3 show that 70 percent of plants have "one-man" or one department responsible for an established painting program. Twenty-four percent of the plants have a paint committee or board responsible for establishing company policy. Departments represented on such a committee are: Engineering, Purchasing and Operations. Determination of when painting is to be done is generally equally divided between Maintenance, Engineering and Operating Departments.

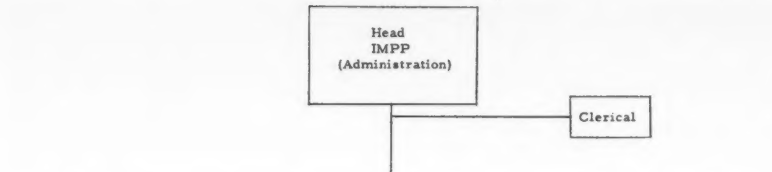

Figure 1—Single department responsibility organizational chart.

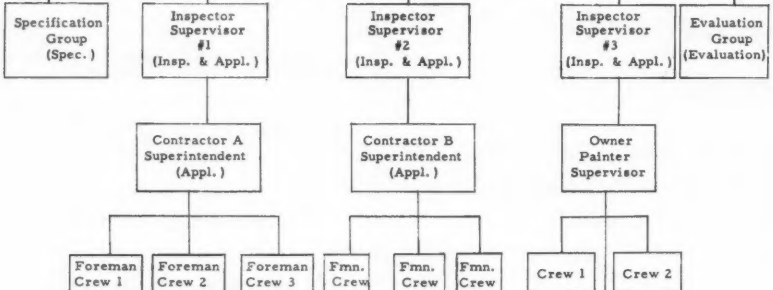

Figure 2—Decentralized organizational chart.

In larger installations, there will be further lines of supervision.[2]

Figures 1 and 2 show organizational charts such as would be recommended under this study.

Owner painters. The tendency in the modern IMPP is to utilize a minimum number of owner painters and these on jobs of a more stabilized nature such as shop work, interior decorative painting, etc.[3]

Large owner painter crews present difficulties in work assignment during inclement weather or to suit job requirements.

Contract painters. The utilization of contract painters is becoming increasingly popular, particularly with the larger industries. Contract crews can be easily varied in size and specialty to fit job requirements, amount of work and weather or season. Company investment in men and equipment is reduced and additional engineering, supervision and inspection services are often available from the contractor.

[2] The results of the questionnaire in supervision are not significant except to indicate a general tendency to overlook supervision as an important part of IMPP. Supervision is either completely lacking in a majority of companies or is to be found in supervisors who have two or more jobs to do.

[3] Questionnaire results do not enforce the above statement since 59 percent of reporting industry does not do any painting with contract labor; however, only 8 percent does not use owner painters. Amount of each type of labor used is illustrated in Table 1 by those industries reporting:

TABLE 1

	Amount of Maintenance Painting Done			
	None	Less than 30%	30% to 70%	More than 70%
By contractor	40	52	21	22
By owner	3	20	18	82

Number of people actively engaged in paint work are as follows:

	Number of Painters			
	None	5–20	20–60	Over 60
Contract painters	61	29	9	5
Owner painters	8	71	18	7

e.g.—Twenty-nine plants of those reporting maintain a group of from 5 to 20 contractor painters and 61 plants have no contractor painters.

Contract painting can be accomplished by:

Cost-plus contract
Firm bid contract
Unit price contract

Inspectors. This group is administratively tied into the IMPP and insures conformance to specifications. Source of personnel can be the industry (company) concerned or an inspection agency. Inspectors need sufficient authority to accomplish the assigned mission.[4]

Reports, Records and Files

Reports, records and files are beyond the scope of this report except that the written and filed portion of IMPP is highly important. Historical records are of utmost importance. Reports and records from which are evolved cost, economics, etc., are mandatory in any IMPP.[5]

Costs and Economics

Economic matters are closely related to reports, records and files. Past efficiency and performance and provision for future costs for estimation and planning are developed from the report and record system. Economic studies provide the key to the IMPP and justify it to management.[6]

Supply of Materials and Equipment

This involves the procurement of all supplies, materials and equipment to accomplish the IMPP. Storage of these supplies and subsequent delivery to the job-site when needed, is also included.

Purchase. The purchase of material is normally handled by a purchasing agency of the company, which acts on advice, recommendations or orders from the coatings division. Materials used most frequently, as quantity justifies, are usually kept in the plant stores or stock division. This entire matter is easily provided for in the normal plant administrative routine.

[4] Sixty-nine percent of the industries delegate the authority to the inspectors to accept or reject work without reference to higher authority. Source of inspectors are reported as follows:

From Engineering	38%
From Maintenance	41%
From Operations & Mechanics	9%
No Inspectors	12%

Fifty-two percent of the inspectors are classified as technical men.

[5] Of the 127 plants reporting, the following categories of information are recorded and/or reported:

	No. of Plants
Dates	85
Surface Preparation	66
System applied	76
Applicator	55
Method of application	57
Weather	30
Amounts of material used	65
Other (costs, man-hours, square feet, etc.)	23

[6] The survey reveals that the following items are developed for study, record and report:

1. Total man-hours or man-days and amount of material for the job.
2. Percentage of maintenance budget used.
3. Lump sum costs by a contractor.
4. Cost per coat of applied material.
5. Cost per mil of applied material.
6. Total cost for the job.
7. Percentage of total investment.
8. Cost per square foot.
9. Cost per square foot per year.
10. Frequency of jobs.
11. Cost per year on a geographical area.

Storage. The safe and proper storage of materials is again provided for in the normal plant administrative organization. In many cases, this matter becomes a problem with bulk items such as sandblasting and sand or paints for major jobs. On large jobs or in the larger plants, job-site or area storage facilities for supplies and material must be provided for in order to minimize time loss through repeated deliveries from the central storage area.

Delivery. As part of the supply plans, the prompt delivery of the necessary material to the job-site is essential. Again, such sensitive material as sandblasting sand presents a particular problem inasmuch as a sufficient amount of material must be available at the job-site, and yet be protected from inclement weather.

Training—Education

With the introduction and utilization of better and more expensive coating materials, the application of those materials becomes increasingly important. Expensive coatings, though designed for maximum performance, very frequently fail prematurely because of faulty application. Each IMPP should provide for a form of training and education for painters, supervisors and inspectors. The company, the union and the contractor may cooperate in this matter. The reporting of this phase of IMPP falls under the jurisdiction of NACE Task Group T-6D-6 on Painter Education.

(7) Of 127 replies, the following illustrates methods used in selection of a coatings system:

Past Usage	72%
Field Tests	73%
Manufacturer's Recommendation	42%
Laboratory Tests	28%
Others*	9%

*Includes: Coatings committee work, standards, cost, reciprocity, contractor specification, "home-office" directive, and recommendations of neighboring industries.

Number of replies giving the current practice in selection of a coatings system for repainting are shown in Table 2.

TABLE 2

	None	Less than 30%	30% to 70%	Over 70%
Prime and one top coat	10	30	26	40
Spot prime and two coats	17	42	20	21
Sandblast and 2-3 coats	35	58	12	4

e.g.—In the system of prime and one coat, 10 plants do none of that type of painting; 30 plants do less than 30 percent of their total work in this system; 26 plants do from 30 percent to 70 percent of their work by this system, while 40 plants do over 70 percent of their painting by this method.

In selection of generic types of coatings, 42 percent of plants use one generic type of coating for most coating work while 58 percent use two or more types of coatings.

Typical replies to generic types used are shown in Table 3.

TABLE 3

Material	DISTRIBUTION		
	Less than 30%	30%—70%	Over 70%
Alkyd	15	19	10
Phenolic	23	3	0
Chlor. Rubber	21	6	1
Vinyl	28	5	0
Epoxy	7	2	1
Mastic	7	3	0
Other*	2	1	3

e.g.—In the case of alkyd type, 15 plants use less than 30 percent of this material, 19 use from 30 percent to 70 percent and 10 plants use over 70 percent of this particular generic type.

*Includes: bitumen, oil, neoprene, inorganic and acrylic.

The individual coatings are selected by these methods indicated by the percentage of those plants reported:

Past usage	21%
Laboratory tests	19%
Field tests	38%
Mfgr's. recommendations	9%
Company standards	2%
Other means	11%

Specification

Selection of Materials

With the many basic generic types of coatings to choose from and thousands of manufacturers producing those coatings, the selection of materials is the major problem of the IMPP. Reference is made to the work of T-6B, NACE, Protective Coatings for Resistance to Atmospheric Corrosion. The problem of selection of materials is resolved to the economical determination of which materials will perform the task. In addition to paints, attention must be given to selection of painting systems, sandblasting abrasives, thinners and other chemicals.(7)

Selection of Equipment

This phase of specification is as important as selection of materials. Quality of cleaning equipment, spray equipment, brushes, etc., seriously affect the job and serious consideration should be given to selection of types and brands. Spare parts stock and availability are important factors. On major equipment, such as air compressors, motor driven staging, etc., service facilities become important. For smaller plants and at installations where major painting is not continuous, equipment may be rented from agencies or from the contractor. In the case of contract painting, it is normal for the contractor to furnish all equipment to accomplish the work. The equipment so furnished should be specified, if not by brand name, at least by type and condition.

Selection of Methods

The specification of methods involves combining the proper coatings selected and the proper equipment, which results in physical application of the material to the steel.

Reference is made to the work of committee T-6B in this respect, as well as coating manufacturer's and contractor's recommendations. Union agreements frequently limit the application technique involved.(8)

Preparation of Specifications

Specifications for protective coatings work varies from the informal and oral to the formal and written. The size of the plant, nature of the work or job, type of contract, time involved and supervision, affect the degree of importance placed upon specifications. In general, larger plants and those jobs involving a fixed cost type of contract use formal and written specifications. The work of NACE—T-6D-2, Specifications, is referred to in this connection.(9)

Responsibility. The responsibility for preparation and dissemination of coating specifications will be determined by the administrative organization followed:(10)

Format. The form for written specifications is recommended in the report of T-6D-2, NACE.

Enforcement of Specifications

Specification of the coatings system does not insure the final desired results from that specification. The adherence to specification must be insured, either formally by an inspection division or informally by plant supervisory personnel.(11)

Application

Application of the specified coatings system is, for the purposes of this report, divided into two types:

Repainting

Repainting is a major job which involves a complete coatings system or coating applied to the area or unit being painted. This may, or may not, require complete or partial removal of one or more previously applied coatings.

Preventive Maintenance

Preventive maintenance is minor work involving maintaining an existing coatings system. This usually involves spot or touch-up work and any complete overcoating is limited to a relatively small area of less than 10 percent of the total job.

The two types of work are distinguished inasmuch as different specifications are involved, different contracts are sometimes used and, particularly different problems of planning and scheduling are to be considered.

(8) Table 4 illustrates, by plants, the coating application methods for each coat:

TABLE 4

	Primer	Intermediate	Finish
Brush	110	96	101
Spray	82	93	108
Hot Spray	6	14	19
Roller	27	29	38

(9) The survey reveals 42 plants have specifications previously prepared for the job; 66 do not have prepared specifications, while 32 use no written specifications at all. Of those using written specifications of some form, 55 plants prepare them for each specific job, while 54 plants use written specifications of a more general nature.

(10) Specifications are prepared by these departments or individuals:

1. Engineering Department: Includes materials engineer, standards department, staff engineer, laboratory and development engineer. 38 percent of plants reporting.
2. Maintenance Department: Includes area engineer, maintenance engineer, plant engineer, mechanical department and buildings division foremen. 34 percent of plants.
3. Corrosion Engineer: Includes paint foremen, coatings technologists and paint inspectors. 18 percent of plants.
4. Operating Departments: Includes general foremen, operating committee, department heads, production and plant manager. 10 percent of plants.

(11) 39 percent of the reporting plants, inspection standards are specified in detail. In 78 percent of the reporting plants, the same inspection standards for work performed are maintained for contractors and owner painters.

Planning. The planning of coatings work involves the long range plans for specific work, either major repainting or preventive maintenance, and, in general, type of work to be done. All phases of the IMPP are to be considered in planning the coatings work of the plant.[12]

Scheduling. The scheduling of coatings work is the planning phase on a short range basis. To be considered here are weather, operational situations, manpower availability, and other details which dictate when a paint job can take place in a given area.

The proper and economical scheduling of preventive maintenance painting is important. Of concern in this phase is the periodic work to be done and scheduled on a time and manpower basis. Amount of work to be done may determine scheduling periods as well as being determined by such scheduling.

Scheduling should also involve plans for unforeseen difficulties such as weather, operational difficulties, etc.

Application. This is the actual application of a coatings system to the steel to be protected either as "Repaint" or "Preventive Maintenance" work. The physical application brings into the program the culmination of the entire IMPP. Supervision is essential to insure proper job set-up, rigging, scaffolding, and work lay-out in the most economical manner. Supervision and inspection during actual work progress insure compliance with specifications. Evaluation has previously selected the proper materials and equipment.

Safety

This important phase of IMPP is the work of NACE Task Group T-6D-5.

Inspection

For the purposes of the IMPP, inspections are made for two reasons:

Routine and Periodic

Routine inspections are made to determine condition of coatings for report and planning purposes. This is designated "routine and periodic" since it is usually done on that basis.

As seen above, inspections are made, in general, at a frequency determined by the severity of the corrosive atmosphere. In many plants, particularly the larger installations, the "routine and periodic" inspection is a formal one followed by a written report to management or the operating departments in order to plan for major work and assist in obtaining funds or authorization to do the work.

Smaller plants may have no formal inspection system, or may elect to retain the services of an inspection agency at periodic intervals.

During Application

Inspections also are made to enforce adherence to specifications "during application" of a coatings system and/or immediately thereafter to determine completion of the contract or agreement.

Evaluation

In the modern IMPP, progress has been so rapid that a program of evaluation of corrosive environment, materials, equipment, methods and performance must be undertaken by any plant regardless of size or industry. The evaulation program itself may be limited to manufacturer's recommendations on the one hand or expanded to a comprehensive testing establishment on the other hand. Manufacturer's literature, publications, NACE proceedings, coating society meetings, laboratory results, field tests, and recorded experience offer sources of information for evaluation purposes.

Environmental

This phase of evaluation is a determination of the corrosive atmosphere to be combatted in steel protection. Temperature, sunlight, humidity and salt-laden air are primary factors produced by nature which must be considered in relation to the physical location of the plant. Fumes and air pollution from adjacent plants must be taken into account. The two "exterior" factors added to local conditions within the plant make up the corrosive atmosphere and will definitely influence the entire IMPP.

Corrosive conditions produced within the plant involve organic and inorganic acids, alkali materials, solvents, dusts, etc. Cooling towers furnish traces of most chemicals involved in a plant process.

In a larger chemical plant, there may be several corrosive environments existing from one portion of the plant to another and each receiving its own consideration in IMPP.[13]

Materials

The evaluation of materials involves the selection of the generic type of coating, the brand or manufacturer and the application characteristics. Also to be considered is the evaluation of expendable materials such as sandblasting abrasives.

An evaluation program may vary widely depending upon size of plant, funds available and end result desired. The evaluation method may consist of one or a combination of:

a. Literature description—manufacturer's literature and recommendations, organizational publications, information from neighboring plants, etc.

b. Laboratory tests—determination of physical characteristics with laboratory apparatus.

c. Field panels—exposure of small panels in the corrosive atmosphere of the plant or area to estimate performance.

d. Large area tests—application of various materials to steel over an area of more than 25 square feet in the corrosive atmosphere. This allows simultaneous evaluation of application characteristics as well as performance data.

e. Limited field tests—field application of materials to the steel to be protected of an area over 100 square feet.

f. Actual performance—information from files and by observation of actual coatings application and performance over a long period of time.

The most important phase of any evaluation program is the proper and accurate correlation of derived data to actual performance.

Equipment

As in the selection of material, the performance of maintenance painting equipment should be evaluated. Not only must the right equipment be selected to do the proper job, but the equipment must be tested for safety.

Methods

The selection of one or more of the methods of application of a protective coatings system is involved in this phase of evaluation. Methods of accomplishing the following are to be considered:

a. Surface preparation
b. Surface pretreatment
c. Priming
d. Application of coatings.

Performance

This is the final evaluation of a completed coatings system combining all the above considerations and is recorded so that the results may be evaluated for the purpose of possible future application.

[12] Determination of when a unit or area is to be repainted is made by one, or a combination of maintenance, engineering and operating departments. Seventy percent of the reporting plants plan and schedule the IMPP in advance. The following departments are involved in this planning phase:

Engineering	44 percent of plants
Maintenance	31 percent of plants
Others	25 percent of plants

Of the plants reporting, 80 percent do painting for other and additional reasons than strict corrosion protection. Other reasons listed are: appearance, housekeeping, preventive maintenance, control heat, lighting, safety and identification. Appearance painting was done by 72 percent of those reporting.

Frequency of repainting is determined by:

a. Inspection — In 94 percent of the plants.

b. Previous coating life — In 11 percent of the plants.

c. In other plants frequency of repainting is determined in various ways: as requested by management, when deemed necessary, according to availability of painters, by statistical evaluation, or by no established policy.

Frequency of inspections is indicated by severity of exposure (see Table 5).

TABLE 5

Exposure	TIME			
	6 Mos. or Less	6 Mos. to 1 Yr.	1 Yr. to 3 Yrs.	Over 3 Yrs.
Severe.....	11	49	13	3
Moderate....	3	36	18	13
Normal.....	1	36	16	26

e.g.—For severe exposure conditions, 49 plants inspect at intervals of 6 mos. to 1 year.

Seventy percent of the plants plan and schedule the painting program in advance. Typical departments involved are: Maintenance, Engineering, Operating and Plant.

[13] Of the plants reporting, 48 percent rate various plant areas for severity of exposure. This rating is expressed numerically in only 17 percent of those conducting such a survey. Other plants use word descriptive identification.

Correlation of Corrosion In a Crude Distillation Unit With Chemistry of the Crudes*

By R. L. PIEHL

About the Author

ROBERT L. PIEHL is Materials Engineer, Standard Oil Co. of Cal., at Richmond. He has a BS in chemical engineering, 1953, University of Wisconsin and has been concerned since that time with corrosion in petrochemical and petroleum industries. He has participated actively in a number of NACE activities.

Abstract

Of the many factors affecting corrosion rates in a crude distillation unit, the one of greatest importance is the tendency for a crude oil to liberate hydrogen sulfide upon being heated. A test procedure has been developed in which the hydrogen sulfide evolution from a crude is quantitatively measured as a function of temperature. Data are presented correlating corrosion rates in various parts of a crude unit with the hydrogen sulfide evolution characteristics of the crude being processed. On the basis of these data, it is concluded that corrosion rates in many parts of a crude distillation unit can be predicted with reasonable accuracy on the basis of hydrogen sulfide evolution and other chemical characteristics of the crude oil. 8.4.3

Introduction

THE FACTORS primarily responsible for corrosion in crude distillation units have been recognized for many years. Because methods have been reasonably well developed for controlling corrosion under these conditions, the corrosion engineer has relatively little difficulty in identifying the causes of crude unit corrosion. He is, however, faced with a more difficult problem when it becomes necessary to predict corrosion rates. He could be called upon to do this either in the design of a new crude distillation unit, or in the event that a new and potentially corrosive crude oil is received at the refinery for processing. Under such conditions, it becomes necessary to estimate the corrosivity of the crude oil on the basis of laboratory test data. The information presented in the following paragraphs constitutes one attempt at a correlation of corrosion data on the basis of certain chemical characteristics of the crude oil.

Development of Hydrogen Sulfide Evolution Test

It has been known for many years that the greatest single cause of corrosion in crude distillation units is the presence of sulfur compounds in the crude. It has also been obvious for some years that there was no direct correlation between sulfur content of the crude and its corrosivity. The controlling factor with respect to sulfur corrosion appears to be not sulfur content itself, but rather the degree to which these sulfur compounds thermally decompose during processing to form more corrosive constituents such as hydrogen sulfide. It should be possible therefore to obtain a measure of the corrosivity of a crude oil by heating it at a given rate and measuring the quantity of H_2S evolved as a function of temperature.

Several test methods have been reported within recent years, that rely on a measurement of hydrogen sulfide evolution as the basis for predicting corrosivity.[1,2] A somewhat similar test has been used for a number of years by the Standard Oil Company of California as an analytical procedure in the evaluation of new crudes to be processed. Specifically, this procedure involves heating a sample of the crude at a uniform rate of 2 degrees per minute in glass apparatus, and bubbling nitrogen through the sample. The evolved hydrogen sulfide is collected in a cadmium chloride solution, from which the H_2S quantities may be determined by conventional analytical procedures.

As a result of using this test, hydrogen sulfide evolution data have been developed for numerous types of crude oil. A plot of H_2S release for a few of these crudes is shown in Figure 1 as a function of temperature. Using these curves, it should be possible to rate the indicated crudes in terms of relative corrosivity at any given temperature. If corrosion rates at any given temperature were proportional to H_2S release, then at temperatures over 600 F. for example, one would expect Santa Maria crude to be more corrosive than any of the others listed.

Correlation of Data

The one problem that obviously presents itself in the use of these hydrogen sulfide evolution curves is the fact that any prediction of corrosion rates for an unknown crude will require a certain background of information on the corrosivity of other crudes of known H_2S release characteristics. Such corrosion data are frequently difficult to obtain, since most crude units do not normally operate for sufficiently long periods of time on a single crude. It was possible, however, to obtain corrosion data and process information on several crude units that have operated almost continually on a single type of crude oil. Also important in obtaining the necessary data were the facts that the units in question were originally built almost entirely of carbon steel with little or no alloy protection, and that excellent inspection records were available.

Flow Diagram of a Typical Crude Distillation Unit

Before proceeding with any further discussion, it should be noted that this discussion pertains to 2-stage crude distillation units of the general type shown in Figure 2. The crude oil entering this type of unit is first heated by heat exchange with some of the hot products. It is then heated further in a directly fired furnace, after which it enters a distillation column operating at essentially atmospheric pressure. The heavy hydrocarbon from this column is further heated in a second furnace. Following this the hydrocarbon enters another distillation column where, due to the existence of a high vacuum, additional components are removed from the crude.

Correlation With Furnace Tube Corrosion Rates

The most obvious place to attempt a correlation of corrosion rates on the basis of hydrogen sulfide release data is in the fired heaters. A careful study of corrosion in these furnaces has shown that an interesting pattern usually exists. Due to the use of some of the heat content of the crude for vaporization, it is characteristically true that the temperature of the atmospheric column bottoms stream is lower than that of the feed to the atmospheric column. As a result, the atmospheric and vacuum columns operate with some overlapping of stock temperatures.

It was noted that while the corrosion rates of tubes in the atmospheric furnace can generally be plotted on a continuous curve as a function of stock temperature, the same thing is not true in the vacuum furnace. This is illustrated by Figure 3. In the vacuum furnace, corrosion rates are usually low until the stock temperature reaches the atmospheric furnace outlet temperature. At about this point, a discontinuity occurs in the curve, and at temperatures above this value, corrosion rates within the vacuum furnace fall on a continuation of the atmospheric column corrosion curve. While this could be partially due to the inherently lower corrosion rates existing in the convection section of the furnace, it is also explainable on the basis of the hydrogen sulfide evolution curves, since if a crude is once heated to a given temperature and the evolved H_2S allowed to flash off, it could be reheated to the same temperature

*Submitted for publication October 26, 1959. A paper presented at a meeting of the Western Region, National Association of Corrosion Engineers, Bakersfield, California, Sept. 29-Oct. 1, 1959.

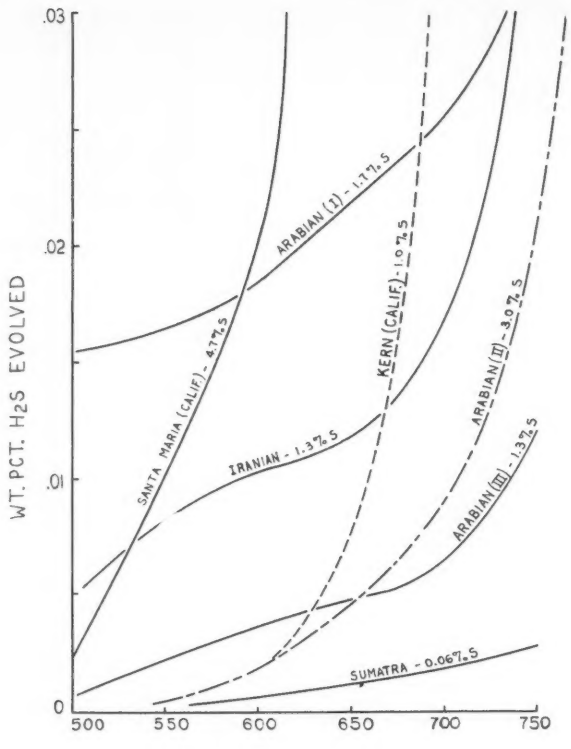

Figure 1—Hydrogen sulfide release from crudes.

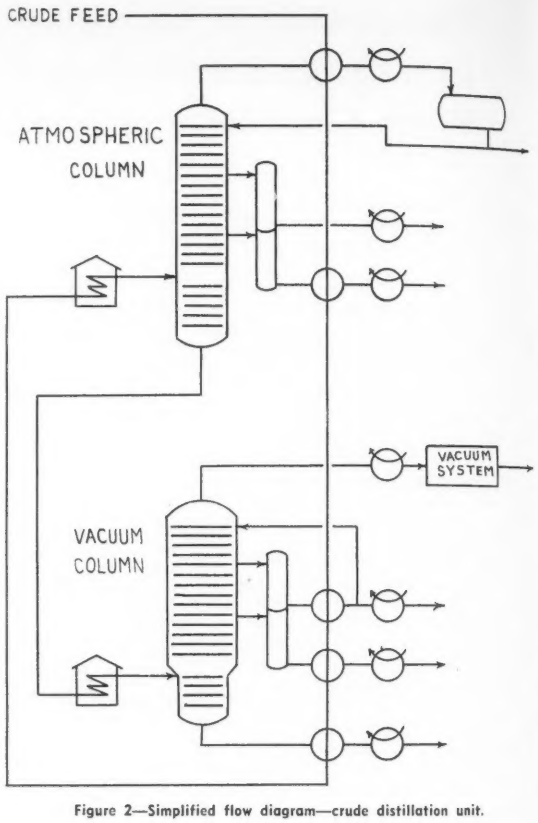

Figure 2—Simplified flow diagram—crude distillation unit.

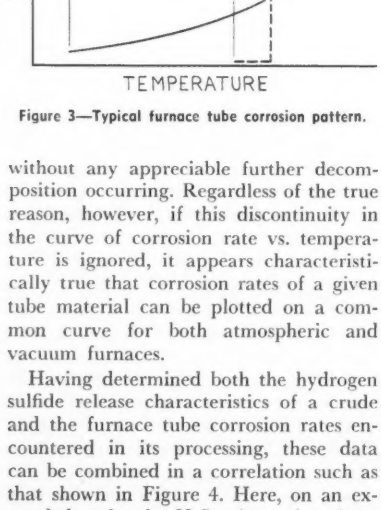

Figure 3—Typical furnace tube corrosion pattern.

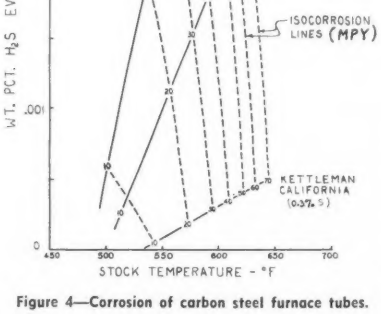

Figure 4—Corrosion of carbon steel furnace tubes.

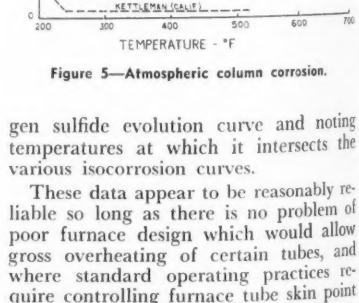

Figure 5—Atmospheric column corrosion.

without any appreciable further decomposition occurring. Regardless of the true reason, however, if this discontinuity in the curve of corrosion rate vs. temperature is ignored, it appears characteristically true that corrosion rates of a given tube material can be plotted on a common curve for both atmospheric and vacuum furnaces.

Having determined both the hydrogen sulfide release characteristics of a crude and the furnace tube corrosion rates encountered in its processing, these data can be combined in a correlation such as that shown in Figure 4. Here, on an expanded scale, the H_2S release data have been plotted as solid lines. On these lines, the corrosion rates of carbon steel have been indicated at the point of applicable temperature and H_2S content. Dashed lines were then drawn through points of equal corrosion rate, giving a series of isocorrosion curves. Using this chart, it should now be possible to determine the corrosion rates of carbon steel furnace tubes as a function of temperature for any crude, merely by plotting the hydrogen sulfide evolution curve and noting temperatures at which it intersects the various isocorrosion curves.

These data appear to be reasonably reliable so long as there is no problem of poor furnace design which would allow gross overheating of certain tubes, and where standard operating practices require controlling furnace tube skin point temperatures to a certain maximum value.

Atmospheric Column Corrosion Rates

From the curves shown in Figure 4, it is apparent that the Arabian crude shows the greatest tendency toward hydrogen sulfide evolution and should therefore be more corrosive than either of the other crudes. It would also be expected that corrosion in the atmospheric column

would be more severe when running Arabian crude. The curves shown in Figure 5 show that this is true. It will be noted that corrosion rates again appear to correlate with hydrogen sulfide release from the crude, except that in the case of the atmospheric column, the only H_2S quantity of interest is the total percentage of hydrogen sulfide released in the atmospheric furnace. In the top part of the atmospheric column, represented by the low temperature end of the curves in Figure 5, corrosion rates are also influenced by the presence of hydrochloric acid, formed by hydrolysis of salts in the crude. The fact that the indicated correlation holds true in the top part of the column is coincidental and indicates only that there is no great difference in the quantities of hydrogen chloride formed.

Vacuum Column Corrosion Rates

This same general approach also should be applicable in the vacuum column, providing that the crude being processed does not contain appreciable quantities of naphthenic acid which might also contribute to corrosion. Figure 6 illustrates the results of a corrosion resistance measuring device test in which the probe was exposed in a sidecut stream from the vacuum column during the alternate processing of a variety of crudes. None of these crudes contained a high enough naphthenic acid content to add appreciably to the corrosion. The temperature in this location, while somewhat variable, averaged about 550 F. It is apparent from the curve that the corrosion rates are roughly proportional to the H_2S content of the system. In the case of both the atmospheric and vacuum columns, it is interesting to note that corrosion rates are usually low in the area below the flash zone. This may be due to the absence of any appreciable quantity of free hydrogen sulfide.

Atmospheric Column Overhead System

Another factor of importance in crude unit corrosion is the effect of salts in the crude which, upon being heated, form hydrogen chloride by a hydrolysis reaction. It is well known that this hydrogen chloride causes active corrosion in both the atmospheric column overhead system and in the top part of the atmospheric column itself. Referring again to Figure 5, it appears fairly obvious that the high corrosion rates noted in the top part of the atmospheric column are due to the temperature being below the dew point of water, thereby permitting the existence of aqueous hydrochloric acid with resulting rapid attack.

Conventional procedures for control of corrosion in this part of the crude unit include the injection of either ammonia or a corrosion inhibitor into the overhead vapor line. The use of ammonia is only partially effective, and its effectiveness decreases as the quantity of HCl present rises. This is due to the fact that, while the net cold condensate from the overhead system may be at a neutral pH, the neutralization of HCl by ammonia is only partially complete in the areas of the overhead system operating at somewhat elevated temperatures.

A series of electrical resistance measuring device tests were run in which probes were placed both in the overhead vapor line ahead of the feed-overhead exchangers, and in the vapor inlet line to the overhead condensers. During this period of time, seven or eight different crudes were processed in the unit, and corrosion rate measurements were made for each. An attempt was made to correlate the resulting data with both the salt content of the individual crudes and with the percentage of hydrogen sulfide present in the system.

The results of this correlation are shown in Figure 7. On these charts, corrosion rates were plotted at the appropriate points on a grid indicating both the H_2S content of the system and the salt content of the crude. An attempt was then made to draw an isocorrosion line on each chart. The accuracy of these data obviously is open to question, due to the fact that certain other variables could influence corrosion rates. The curves do, however, point out several factors of interest. In all cases, the corrosion data were obtained while injecting ammonia into the system in a quantity sufficient to maintain the pH of the water condensate at about 7. It is apparent from the data that ammonia injection alone is not always sufficient to control the corrosion, and that an inhibitor of the organic type could perhaps be used to advantage. The data also indicate that hydrogen sulfide is capable of contributing substantially to corrosion in this part of the system, and may be a factor of equal or greater importance than the hydrogen chloride.

Accuracy of Data

Two of the correlations previously presented were based on data obtained through use of an electrical resistance measuring device, since this appeared to be the only way that the necessary information could be obtained on the effect of varying conditions on corrosion rates in a fixed location. Prior to the period in which numerous types of crudes were processed, the crude unit in which these data were obtained had operated for many years on only a single crude. Corrosion rates under these conditions had been accurately measured by conventional inspection methods. It was subsequently noted that, when running this particular crude alternately with other types of crude oil, the corrosion rates indicated by the electrical resistance measuring device appeared to agree quite closely with those previously obtained by physical measurement of equipment. It was also found that the corrosion rates measured by the device showed a high degree of reproducibility when duplicate runs were made on each variety of crude.

Conclusions

The data presented show a reasonably well developed correlation between furnace tube corrosion rates and the hydrogen sulfide evolution characteristics of the crude oil being processed. Sufficient data also are given to indicate that corrosion rates in most other areas of a crude distillation unit can be correlated on the basis of such factors as H_2S evolution and salt content of the crudes. For this reason, it is believed that corrosion rates in a crude unit can be predicted with a fair degree of accuracy on the basis of operating conditions and the chemical characteristics of the crude oil to be processed.

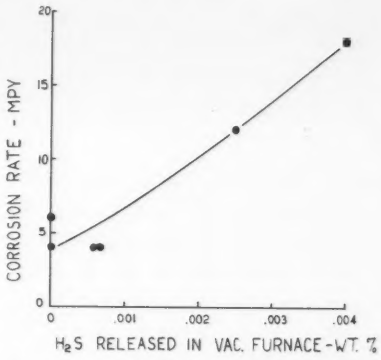

Figure 6—Corrosion of carbon steel in 550 F vacuum column sidecut.

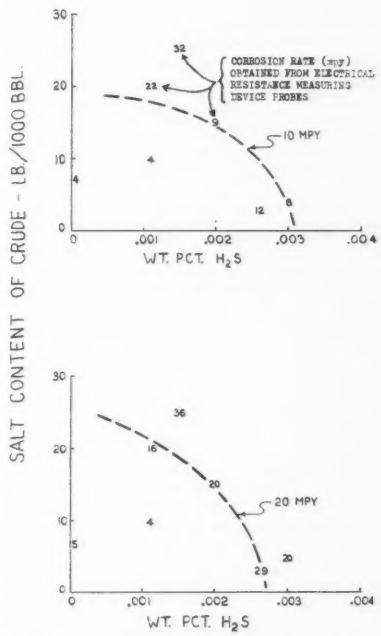

Figure 7—Atmospheric column overhead system (corrosion rates of carbon steel). Top graph is for inlet of overhead exchangers; bottom graph is for inlet of overhead condenser.

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DISCUSSIONS

High Temperature Metal Deterioration in Atmospheres Containing Carbon Monoxide and Hydrogen by W. B. Hoyt and R. H. Caughey, Corrosion, Vol. 15, No. 12, 627t-630t (1959) Dec.

Comments by T. E. Evans and H. Lewis, The Mond Nickel Co. Ltd., Birmingham, England:

About one and a half years ago we had the opportunity of examining some samples of corroded 25 percent Cr, 20 percent Ni austenitic steel tubes and tube plate taken from various parts of a plant which was almost certainly the one described by the authors. This examination revealed essentially similar features of attack to that described in the paper. However, there were one or two observations which led to the supposition that the unusually severe attack encountered in this plant could not be satisfactorily attributed entirely to carburization, although this undoubtedly had played a major role.

In their discussion the authors have considered three alternative explanations of the observed metal wastage: (1) That it is a form of acid attack caused by entrainment of acidic constituents in the feed gas, (2) That it is a consequence of cyclic conditions in the plant as a result of which the metal surface is alternately carburized and oxidized, and (3) That it is due to carburization induced by chemically active carbon deposited on the surfaces of the tubes from the catalytic decomposition of carbon monoxide. Of these three theories the authors apparently find least difficulty in accepting and developing the third. It seems to us that the separate processes described in these theories are not necessarily without effect upon one another, and that there are some additional features not taken into account by the authors that merit consideration.

With regard to the first theory, it is important not to overlook the influence which salts such as chlorides and sulfates originally present in the wash water passing through the scrubber may have exerted in the initiation of localized attack. Examination by us of sound areas of the inside wall of a 25/20 tube which had failed in a primary pre-heater in the manner described in the paper revealed indications of pitting similar to that induced by aqueous chloride media. The failure to detect inorganic salts in the corrosion products on the interior of the tube is not necessarily an effective demonstration of their absence at some earlier stage; the total amount needed to initiate attack need only have been small and any traces would probably have been removed in the course of the subsequent wastage.

Although this mechanism does not account for the severe metal loss that occurred it seems possible that it may have played a critical role in initiating sites for subsequent carburization, and thus have acted as a trigger mechanism. It would serve to explain the otherwise rather surprising feature that the temperature at which carburization attack was found to occur in the primary preheaters was unexpectedly low, namely 900-1000 F.

The second mechanism considered by the authors is to the effect that metal loss occurred by oxidation of surface material in which the chromium content of the matrix had been effectively depleted by prior carburization. The authors discount this as a complete explanation on the grounds that this form of attack persisted after air had been eliminated from the operating cycle. In our experience this type of attack is not necessarily restricted to atmospheres which are alternately carburizing and oxidizing; it has been observed that when Ni-Cr-Fe and Ni-Cr heat resisting alloys are heated in carbon monoxide, penetration of carbon and oxygen is simultaneous and that one does not necessarily follow upon the other.

The possibility remains that the suggested catalytic decomposition of carbon monoxide to give a deposit of chemically active carbon on the metal surface is a factor in the carburization process, although soot formation is usually regarded as a hindrance to carburization and is avoided in gas-carburizing process. The data in Figure 1 of the paper indicate that the carbon monoxide content of the feed and product gases is approximately the same and in view of this it might be expected that if carbon monoxide alone were responsible the attack would have manifested itself both on the inside and outside of the tubes at about the same rate and to about the same extent. As this was not so it seems reasonable to infer that the wastage was not due to the action of carbon monoxide alone. In this context it may be relevant to consider the relative carburizing potential of the feed and product gases. Hydrocarbon gases are generally more potent carburizing agents than carbon monoxide and the fact that attack developed much more rapidly and severely on the inside of the tubes than on the outside may be associated with the higher hydrocarbon content of the feed gas as compared with that of the product gas. It therefore appears probable that both carbon monoxide and hydrocarbon gases contributed to the carburizing attack.

As the authors imply in the "Introduction" to the paper, it is perhaps a surprising feature of this case that wastage of the tubes should have occurred with such severity and rapidity. It appears to us that the facts permit of no simple explanation based on a single mechanism of corrosion, but rather that a more complex interpretation along the lines discussed above is required, which takes into account the interaction of effects produced by various constituents in the gas streams.

Discussions of technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from November through April will appear in the June issue and those from May through October in the December issue.

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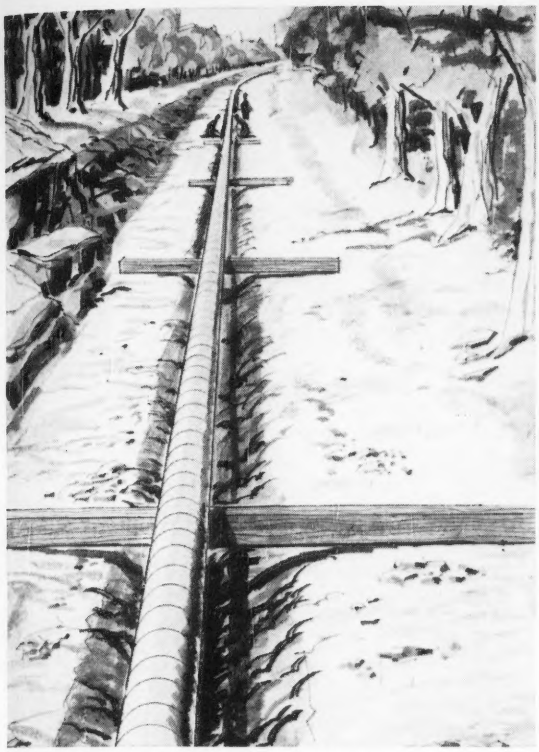

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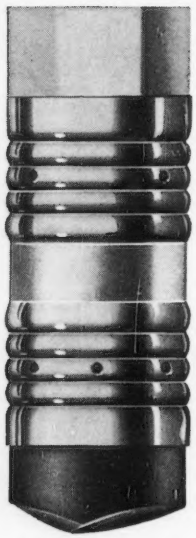

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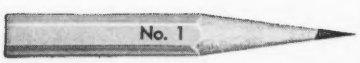

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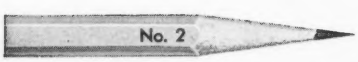

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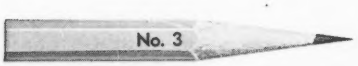

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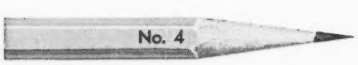

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